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ABSTRACT

This monograph has four main objectives: (1) to define the field of ergometrics, (2) to identify some potential applications of ergometrics to problems in occupational or career education, (3) to review the relevant research literature, and (4) to suggest some conceptual approaches that might be used in conjunction with ergometric procedures. Ergometrics, which is psychometrically based work analysis, stems from the need for a comprehensive taxonomy of human performance as related to occupational variables. Various studies of job attributes and commonalities are cited, and possible rating methods for human behavior, work activities, and skill requirements are discussed. Theories and research related to work motivation, learning capabilities, factor analysis, and occupational data could be utilized for systematically developing and applying ergometrics to career education. The conceptual scheme of occupational clustering was a major impetus for proposing this new systematic approach to educational problems. (AG)

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# "ERGOMETRICS": A SYSTEMATIC APPROACH TO SOME EDUCATIONAL PROBLEMS

J. W. CUNNINGHAM

ERGOMETRIC RESEARCH AND DEVELOPMENT SERIES
REPORT NO. 2

J. W. CUNNINGHAM
PROGRAM DIRECTOR

CENTER MONOGRAPH NO. 7

CENTER FOR OCCUPATIONAL EDUCATION
NORTH CAROLINA STATE UNIVERSITY AT RALEIGH
1971

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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# "ERGOMETRICS": A SYSTEMATIC APPROACH TO SOME EDUCATIONAL PROBLEMS

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Report No. 2 of the Ergometric Research and Development Series

Program Director: J. W. Cunningham

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Center Monograph No. 7

1971

CENTER FOR OCCUPATIONAL EDUCATION
North Carolina State University at Raleigh

Project No. BR 7-0348

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PREFACE

Although the work on which this report is based was launched long before Dr. Sidney P. Marland, Jr., U. S. Commissioner of Education, designated career education a high priority for the U. S. Office of Education, this work is of immediate import for the current movement. Career education is based on the principle of equal educational opportunity as applied to preparing youth and adults for work roles in American society; that is, each individual should have access to quality education which will prepare him for the work role in society which is commensurate with his attributes, and he should have access to education which will advance his career or prepare him for new careers.

The differentiations of the occupational structure--that is, the differentiation of attributes of occupations, the differentiation of the human attribute requirements of these occupations (or, more aptly, clusters of occupations), the differentiation of the set of attributes that distinguish one individual from another, and the differentiation of the social values of the residual group to which the individual belongs--taken together, indicate that the crux of career education resides in individual decision-making and the wherewithal to act on decisions in terms of obtaining education for the development of skills, knowledges, and attitudes.

The differentiation of the set of attributes that distinguish one individual from another is the domain of psychometrics. The differentiation of the set of attributes that distinguish one occupation from another is the domain of "ergometrics," a term coined by Dr. Cunningham. Ergometrics, therefore, may well become a companion discipline to psychometrics, the former field centering on the attributes of occupations and the latter on the attributes of the individual.

Whether "ergometrics" becomes a household word is a debatable and unpredictable point. The choice of the term, while intriguing, is not the point of issue here. The real points are that man has advanced by sharpening his powers of observation, description, and measurement, and that career education will advance man by sharpening the powers of the individual and the personnel responsible for providing him with quality and appropriate educational experiences to describe himself and the content of the career--the series of occupations--in which he aspires to gain satisfaction for himself and contribute to the welfare of society.

Although it has become commonplace to speak of the "world of work" as though it were an external celestial body, the fact is that one's work is an extension and expression of one's personality. It is impossible to distinguish the individual from his acts. The matching of men and jobs may have a repugnant, mechanistic connotation; but failure to do so does a disservice to the individual and to society.

A real danger occurs when the individual is forced to chart his career on the basis of inadequate information, or when he is not at liberty to exercise his options. To the extent that knowledge is liberating, Dr. Cunningham is contributing to the liberation of the individual from the shackles of inadequate knowledges about the attributes of the possible careers open to him. The knowledge should be of value not only to the individual in choosing the occupation to start his career, but in the transferability of careers.

The Center is indebted to Dr. Cunningham for his work and to the Center's technical and editorial staff for their assistance in the production of this report.

John K. Coster
Director

TABLE OF CONTENTS


| | Page |
|---|---|
| PREFACE | ii |
| INTRODUCTION | 1 |
| Occupational Clustering | 1 |
| The Taxonomy Problem | 4 |
| ERGOMETRICS: A SYSTEMATIC APPROACH | 6 |
| Work Description and Classification | 9 |
| Curriculum Development and Revision | 9 |
| Curriculum Evaluation | 11 |
| Test Development | 12 |
| Guidance, Placement, and Selection | 13 |
| Educational Planning | 14 |
| Job Design | 14 |
| Research | 15 |
| STUDIES OF JOB DIMENSIONS AND COMMONALITIES | 16 |
| Some Definitions | 16 |
| Basic Attribute Requirements of Jobs | 18 |
| Knowledge and Skill Requirements of Jobs | 23 |
| Activity Components of Jobs | 26 |
| Activity Statements Applicable to Restricted Ranges of Jobs | 27 |
| Activity Statements Applicable to Jobs in General | 31 |
| DISCUSSION | 41 |
| LIST OF REFERENCES | 48 |

## INTRODUCTION

One of the major problems facing the educator is that of preparing today's student for a rapidly changing and somewhat unpredictable world of work. Among the many questions facing him are these: What do you teach the student? How do you counsel the student? How do you place the student in curricula and jobs? And how do you evaluate your results? It is the reviewer's contention that the field of "ergometrics," or psychometrically based work analysis, can contribute to the answers to these and other related questions.

This paper has four main objectives: (1) to define the field of ergometrics, (2) to identify some potential applications of ergometrics to problems in occupationally related (or career) education, (3) to review the relevant research literature, and (4) to suggest some conceptual approaches that might be used in conjunction with ergometric procedures.

### Occupational Clustering

Since a recognition of the need for systematic work analysis in occupational education grew from the reviewer's involvement with the concept of "occupational clustering," it was felt that a brief discussion of the clustering concept and its development would serve as a useful introduction to the topic of ergometrics.

In recent years occupational clustering, or the grouping of occupations with similar educational requirements, has been advocated as a possible way of dealing with problems related to structure and organization within the field of occupational education. Underlying this concept is the assumption that an individual exposed to a curriculum designed for a group of related occupations should be better prepared--compared with the person trained for a specific job or occupation--to adapt to changing work demands. Discussion of the cluster concept can be found in the following sources: Cunningham (1969), Maley (1966), Rahmlow (1969), Sjogren (1969), and Sjogren and Sahl (1966).

The apparent need for greater flexibility on the part of today's worker is emphasized by L. A. Lecht (1969) in the following statement:

> Beginning with the first position held for at least six months, the typical member of the labor force without a college education, to cite a current estimate, holds twelve different jobs in a forty-six-year working life. Only one man in five in this group can anticipate remaining in the same major occupational category for his entire life. Except for those in the skilled craft, service, and white-collar occupations, most workers in the non-college group do not have careers. They usually hold a series of jobs, which are likely

> to be unrelated or only loosely related to each other. The education and training that is significant for these people would stress increasing the options available to individuals in a changing society, rather than training them for a first or second job. (p. 111)

In another discussion of this problem, W. L. Face (1967) suggests the following implications for educations:

> These needs [related to worker flexibility] rather clearly express the guidelines that vocational educators must keep in mind as they develop new programs for the future. They cannot be met by specialized skill training which is appropriate for one and only one occupation. To spend valuable educational time in this manner may be of some immediate value to the student, but it places him in a very tenuous position as he faces the world of work. . . . Increasingly, we find in the literature that various leaders in industrial education have taken the position that specialized and more advanced vocational training must be provided by apprenticeship programs or on-the-job experience. . . . (p. 99)

Dillon and Horner (1968) comment in a similar vein:

> It is impractical to have a different instructional program for each job title. The structure of the labor force is changing constantly. New occupations are being created as emerging technologies develop demands for new competencies, and existing occupations become obsolete. Occupational mobility is constantly increasing, not only in terms of geographical mobility but vertically toward more demanding occupations in terms of skill and educational requirements. . . . (p. 50)

The preceding comments and those of other writers in the field of occupational education (e.g., Gardner, 1961; Morgan and Bushnell, 1966; Nelson, 1967; Rahmlow, 1967) suggest, then, that efforts must be made to provide students with educational experiences that prepare them for appreciable variations in occupational demands. This need for transferable capabilities is further emphasized by findings that vocational interests often change in the period when youths are enrolled in occupationally related curricula. Thus, Ginzberg et al. (1951, pp. 95-117) refer to the "period of realistic choices," and Strong (1943) has found that though age differences in interest measures are less significant than occupational differences, appreciable interest changes do occur between the ages of 15 and 25. More recently, Flanagan (1965) has compared career choices made by students while enrolled in high school with their choices one year after high school graduation. The results of Flanagan's study suggest that career choices made in high school are relatively unstable: only 29 percent of the male and 37 percent of the female students who indicated career choices in the eleventh grade made identical career choices one year following high school graduation. A study with even stronger implications for occupational education was conducted by Eninger (1965), who reported finding

a relatively low degree of correspondence between trade training during high school and initial job placement.

Frantz (1967) provides a succinct summary of the concerns expressed by other writers:

> In the first place, there is a need to provide students with a greater degree of mobility on a geographical basis. Second, there is a need for increased mobility within an industry or occupation. Third, students must be trained so that they can adapt to technological change. And finally, students must be given a greater flexibility in their occupational choice patterns. . . . (p. 85)

It was from this context that the occupational-cluster concept emerged.

Support for the cluster concept is found in the following recommendation by a panel of consultants to the U. S. Department of Health, Education, and Welfare (1963):

> Basic vocational education programs should be designed to provide education in skills and concepts common to clusters of closely related occupations. The curriculum should be derived from analyses of common features of the occupations included. These students should receive specialized or more advanced vocational training later in post-high school programs, apprenticeships, or on-the-job experiences. . . . (p. 227)

A more detailed discussion of the need, viability, and acceptance of the cluster approach is presented by Maley and Mietus (Maley, 1966; Maley and Mietus, 1969).

Not only has the cluster concept been discussed and advocated; it has also been implemented in a number of educational settings and will undoubtedly influence occupational curricula in the future. D. E. Maurer (1967) has reported one such program--undertaken by the Gary, Indiana, Public School System--which was designed around the following occupational clusters: building construction and maintenance, business and commerce, communications, extractive industries, health and personal service, marine trades, mechanics and metal working, productive services, technology, and textiles and leather. Another program, reported by Morrison (Morrison, 1967; Morrison and Lecznar, 1966), was developed at the Quincy, Massachusetts, Vocational-Technical School. One aspect of the Quincy project involved the identification of 11 occupational areas (clusters), and over 200 specific occupations within these areas, for curriculum development purposes. Maley and Mietus (1969) have also reported a cluster program, initiated in four Maryland counties, which was designed around three occupational clusters: construction, metal forming and fabrication, and electro-mechanical installation and repair. Quite recently, the U. S. Office of Education has awarded a grant to the Center for Vocational and Technical Education at Ohio State University to develop and test, in cooperation with six school districts,

a "school-based" program in career education centered around 15 occupational clusters (Marland, 1971; National School Public Relations Association, 1971). Other cluster programs are either under way or in planning stages in the following locations: The Multnomah County Intermediate Education District, Portland, Oregon; the Public Schools of the District of Columbia; the Dallas Independent School District; and the Detroit Public Schools.[1]

## The Taxonomy Problem

Although occupational clustering would appear to offer some promise for the complex and somewhat disorganized field of occupational education, two questions basic to this approach have thus far received little attention: What are the characteristics on which occupations are to be described, compared, and classified for educational purposes? And even assuming we could establish valid clusters of similar occupations without first defining a set of variables (or descriptors) for classification purposes, how would we then determine what common denominators should be incorporated into cluster curricula?

These and other questions pertaining to articulation between the educational and work domains point to the need for a taxonomy of human work suitable for educational purposes. The taxonomy problem is not, of course, unique to occupational education. The biologists have been wrestling with this problem for years and have made impressive progress, although not without a tremendous investment in time and resources. It is estimated that there are currently some 7,000 zoological taxonomists and 1,900 plant taxonomists working on the classification of organisms (Haggard, 1963). Only recently, however, has a systematic effort been directed toward the problem of describing and classifying the characteristics of human performance (Hackman, 1968; Haggard, 1963). Some notable examples of this relatively recent trend include: the contributions of Cotterman (1959), Gagné (1970a), and Stolurow (1964a, 1964b, 1966) in the area of human learning; the factor-analytic studies of Fleishman (1964, 1967a) and Guilford (1967, 1971) in the psychomotor and cognitive ability domains, respectively; the task classification effort currently under way at the American Institutes for Research (Chambers, 1969; Farina, 1969; Farina and Wheaton, 1969; Wheaton, 1968); and E. J. McCormick's studies of job dimensions (Palmer and McCormick, 1961; McCormick, Cunningham, and Gordon, 1967; Jeanneret and McCormick, 1969).

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[1]This information was obtained through personal communication with the following individuals: A. C. Goetz, Multnomah County Intermediate Education District, September 16, 1971; F. B. Lawrence, Public Schools of the District of Columbia, September 17, 1971; W. T. Denton, Dallas Independent School District, June 30, 1971; and M. C. Kavieff, Detroit Public Schools, September 16, 1971.

After reviewing these and other initial taxonomic efforts, however, Wheaton (1968) has concluded that ". . . behavioral taxonomy is still in its infancy." Furthermore, as noted by Haggard (1963), it is unreasonable to expect that this problem will be easily resolved:

> . . . the derivation of a logically inter-related structure of classification of behavior should not be viewed as a short-term effort requiring for its successful completion only that several competent psychologists set about to organize the area. Systematics has a long history in the other life sciences; yet organization is far from complete, though much has been accomplished toward building and encompassing structure and though many limited special purpose structures have been developed. . . . One could not expect, then, that a few psychologists or agencies could soon establish criteria for behavior classification, formulate a structure and expand it to take care of all of the properties of behavioral phenomena, stabilize terminology, and derive precise methods for rapid identification of phenomena. (p. 8)

Chambers (1969) offers a similar conclusion:

> We do not believe that the development of a comprehensive classification system [for human performance] can be accomplished by few individuals working in isolation. Just as our complex technologies are forcing us to indulge in large-scale research in which more and more variables are manipulated, so too are our information needs forcing us toward larger scale information handling systems. Coordinated and standardized efforts by many persons will be required to solve both the technical and practical problems of classification. (p. 75)

It would appear, then, that the development of a comprehensive taxonomy of human performance applicable to the wide variety of problems in industry, education, and the laboratory will, at best, be realized in the somewhat distant future. In the interim, we must, of course, deal with immediate problems as best we can. It would thus behoove the educationist to invest some time and resources in developing conceptual frameworks and procedures for transforming information from the work domain into information applicable to educational problems; for if the avowed purpose of education is to prepare the individual for the adult society, then relationships must be established between the tasks and conditions imposed upon the student and those which he or she is likely to encounter upon leaving the educational environment. Gagné (1970b) makes this point in suggesting that ". . . formal education be made relevant by deriving its objectives from the life activities of adults in a modern society." (p. 18) Although concepts, principles, and techniques from other fields could (and should) be applied to this problem, it would be unwise to await further developments in these fields before undertaking to impose some conceptual structure upon occupational education.

## ERGOMETRICS: A SYSTEMATIC APPROACH

In order to be useful for educational purposes, a work taxonomy should have the following characteristics: (1) its conceptual structure should be derived from established principles and theories of human behavior; (2) it should deal with work at different levels of complexity, ranging from occupational categories (or clusters) to rather narrow classes of tasks and task characteristics; (3) it should identify developmental progressions (or transfer sequences) in the acquisition of task capabilities, beginning with classes of relatively simple tasks learned in childhood (e.g., educational skills) and extending through classes of occupational tasks; (4) its elements, or descriptors, should be general enough for application to a variety of occupations, and yet specific and concrete enough to have curricular and other educational implications; (5) its elements should be linked to human dimensions for which there are standardized measures (i.e., tests in the cognitive, affective, and psychomotor domains); and (6) it should provide information that can be readily transformed into products for educational use (e.g., curricula, guidance systems, evaluation procedures, and tests).

In approaching a problem such as this, one must make decisions concerning both methodology and theory. In regard to methodology, the reviewer has concluded that established procedures in the areas of job analysis and psychological measurement come closest to meeting the requirements for the proposed descriptive and taxonomic scheme. While some of the activities of the industrial engineer can be subsumed under the heading of "job analysis," the job-analysis procedures developed by the industrial psychologist seem more applicable to the problem. The industrial engineer is concerned primarily with the physical aspects of work (usually at a relatively molecular level); the industrial psychologist focuses upon the more molar, human aspects of work (Blum and Naylor, 1968, p. 491).

Although it would be difficult to pinpoint the beginning of "job analysis" in the latter sense, its history might be traced to such sources as the writings of E. K. Strong and R. S. Uhrbrock (Strong and Uhrbrock, 1923; Uhrbrock, 1922, 1931, 1934), Viteles' job psychograph (Viteles, 1932), and the work on occupational ability patterns at the University of Minnesota (Dvorak, 1935). The major developments in job analysis since the 1930's have resulted from efforts such as the following: the work of C. H. Lawshe and E. J. McCormick at Purdue University (Lawshe et al., 1944, 1945, 1946, 1947, 1948, 1949, 1955; McCormick et al., 1954, 1957, 1960, 1967a, 1967b, 1969b); C. L. Shartle's work at Ohio State University (1942a, 1942b, 1943, 1944, 1946, 1959); the efforts of the U. S. Employment Service in connection with the preparation of the Dictionary of Occupational Titles (Fine, 1955a, 1955b, 1958; Fine and Heinz, 1957, 1958; Lewis, 1959; Studdiford, 1951, 1953; Trattner, Fine, and Kubis, 1955); and various job-analysis projects conducted by the U. S. Air Force (e.g., Christal et al., 1960, 1961, 1963; Madden, 1960a, b, c, d, 1963a, b, c; Madden et al., 1963, 1964; Morsh et al., 1959, 1961, 1965, 1966, 1967, 1969; Rupe, 1952, 1956; Rupe and Westen, 1955a, 1955b).

The history of psychological measurement is better known and more inclusive than that of job analysis, and will not be summarized here. It should be noted, however, that job analysis, as practiced by the industrial psychologist, frequently draws from the field of psychological measurement.

The question of an appropriate theoretical base for the proposed taxonomic scheme is not an easy one. While the conceptual apparatus should be compatible with the measurement approach mentioned earlier, there is much latitude within this constraint. Tests have been developed within such diverse theoretical contexts as information processing (Guilford, 1966, 1967), reinforcement expectancy (Rotter, 1966), formulations concerning human needs (Edwards, 1959), etc.; and psychological scaling procedures can be applied in the quantification of any variables (e.g., descriptions of task and job elements) which elicit reliable human judgments. Hence, the proposed methodological approach could be used with any theory (or theories) of human behavior that did not preclude the application of psychometric procedures and correlational statistics.

Although there are several methodological approaches to job analysis (Blum and Naylor, 1968, pp. 494-495; Tiffin and McCormick, 1965, pp. 60-65), the trend in this field seems to be toward the use of rating scales in conjunction with sets of common job elements, or variables. In recent years, a good deal of research effort has gone into testing the merits of various types of job elements and rating procedures in job analysis (e.g., Cragun and McCormick, 1967; Gordon and McCormick, 1962; Madden, 1960b, c, d, 1963b, c; McCormick and Ammerman, 1960; McCormick and Tombrink, 1960; Peters and McCormick, 1966). Moreover, there has been an increasing interest in establishing conceptual bases for job and task analysis, as evidenced by the work of such investigators as McCormick (McCormick, Cunningham, and Gordon, 1967; McCormick, Jeanneret, and Mecham, 1969b); Fine (Fine, 1969; Fine and Heinz, 1958); Miller (1955, 1962); Hamreus and Langevin (1967); Sjogren (Sjogren, Schroeder, and Sahl, 1967); Chambers (1969); and Farina and Wheaton (1969).

In light of the increased emphasis upon psychometric procedures in job analysis--in comparison to other types of procedures (e.g., written descriptions, work diaries, and films)--it would seem appropriate at this time to coin a new and more specific term for this particular approach to the study of work. One label that might suffice for this purpose is ergometrics, which could be defined as the application of psychometric principles and procedures to the study of human work. ("erg" derives from the Greek word ergon, meaning work.) This field of investigation would draw from theories and principles of human behavior, as well as from established procedures in psychological measurement and job analysis. It would deal with at least four basic kinds of problems: (1) the definition, quantification, and classification of work variables; (2) the establishment of relationships between work variables and existing measures of human attributes (i.e., tests in the cognitive, psychomotor, and affective domains); (3) the

development of measures of work-related human attributes, or behavioral potentials (such as vocational ability tests and interest scales); and (4) the study of the nature of the relationships among various work-related variables. Accordingly, research in ergometrics, like any other field of research, would involve theory building, measurement, classification, and hypothesis testing. Because of its emphasis on psychometric procedures, ergometrics might be characterized as a "nomothetic" rather than an "idiographic" approach to the study of work (Allport, 1937; Tyler, 1965)--i.e., an approach emphasizing the common dimensions rather than unique characteristics of tasks, jobs, and occupations.

At this point, a distinction should be made between the terms "ergometrics" and "ergonomics." ("Nomics" derives from the Greek word nomikos, meaning law--cf. Dukes-Dobos, 1968). Ergonomics is a term applied in Great Britain and Europe to an established field of activities that would fall under the heading of "human factors engineering" in the United States (McCormick, 1970; McFarland, 1971). A definition of this field can be drawn from the following statement concerning the objective of the Ergonomics Research Society (1964):

> The objective is to promote learning and advance education in the subject of the relation between man and his environment, the design of the equipment with which he works and particularly the application of anatomical, physiological, and psychological knowledge to the problems arising from his equipment and environment. (p. 5)

Two distinctions between ergonomics and ergometrics might be drawn from the foregoing statement and the previous definition of ergometrics: (1) ergonomics places considerable emphasis upon the physical and physiological aspects of work, whereas ergometrics is more concerned with the psychological aspects of work; and (2) ergonomics typically deals with work at a more molecular level than ergometrics--e.g., specific physiological, sensory, and motor responses (in relation to work performance), compared with more molar behavioral variables, such as McCormick's worker-oriented activities (McCormick, 1959, 1964). A further distinction is the one Cronbach (1957) makes between engineering psychology, which is subsumed under ergonomics (Grether, 1968), and personnel psychology, the field within which ergometrics has developed. According to Cronbach, engineering psychology, as an outgrowth of experimental psychology, focuses upon group means, whereas personnel psychology relies primarily upon the correlational approach and the existence of individual differences. Cronbach notes, however, that "The greatest social benefit will come from . . . the joint application of experimental and correlational methods." (1957, p. 679) A similar argument could be made for a complementary relationship between ergometrics and ergonomics.

Finally, some comments should be made concerning the potential applications of ergometrics in the field of occupational education. Essentially, the function of ergometrics would be one of describing, structuring, and translating the world of work for educational (as well as other) purposes. Some of the uses of systematic job analysis proposed by previous writers (Morsh, 1965, 1969; Tiffin and McCormick, 1965;

Zerga, 1943) could, with modification and extension, be offered as possible applications of ergometrics in education. These are shown in Figure 1 and discussed briefly in the following paragraphs. Figure 1 is intended merely as an illustrative device suggesting how ergometrics could mediate between the world of work and the educational system; that is, how ergometric procedures could be used in transforming information from the work domain into information applicable to educational problems. The arrows in the diagram indicate the directions of information flow.

## Work Description and Classification

As suggested earlier, there is a need for a taxonomic system which would structure the work domain in a way that would be useful for educational purposes. One prerequisite for such a system would be the definition of variables by which occupations, jobs, and tasks could be described, compared, and grouped. This requirement is noted by Tiffin and McCormick (1965) as follows: "In order most adequately to be able to compare jobs . . . it is necessary . . . to be able to identify or quantify job elements or characteristics in relatively standard terms. We could thus think in terms of possible 'common denominators' of jobs, or in terms of the 'dimensions' of jobs." (p. 66) In another comment on this problem, McCormick (1964) suggests that "If basic job dimensions of these types can be identified, it would seem that, through job analysis procedures it would then be possible to characterize each job in terms of its 'level' on each dimension; each job might then have something of a profile that would characterize it in terms of such dimensions." (p. 1) Farina (1969) and Wheaton (1968) propose essentially the same approach, which they term "quantitative classification," for purposes of task description and classification. This approach has, in fact, been employed in a number of studies of job and occupational commonalities (e.g., Hamreus and Langevin, 1967; McCormick, Finn, and Scheips, 1957; Orr, 1960; Sjorgen, Schroeder, and Sahl, 1967). It would therefore seem reasonable to consider the application of ergometric procedures for the purpose of defining and quantifying work dimensions having curricular and other educational implications.

## Curriculum Development and Revision

Although this statement would evoke a debate within almost any group of educators, it appears to the reviewer that the primary purpose of education, as it is presently conceived in our society, is to prepare the individual to ultimately perform tasks, the outcomes of which will benefit society as well as himself--i.e., to prepare the individual for work.[2] According to one conception (Gagné, 1962a, 1970a; Cunningham,

[2]It is quite possible, of course, that future technological and social changes will necessitate a modification of our present conception of "work" and how one should be compensated for it.

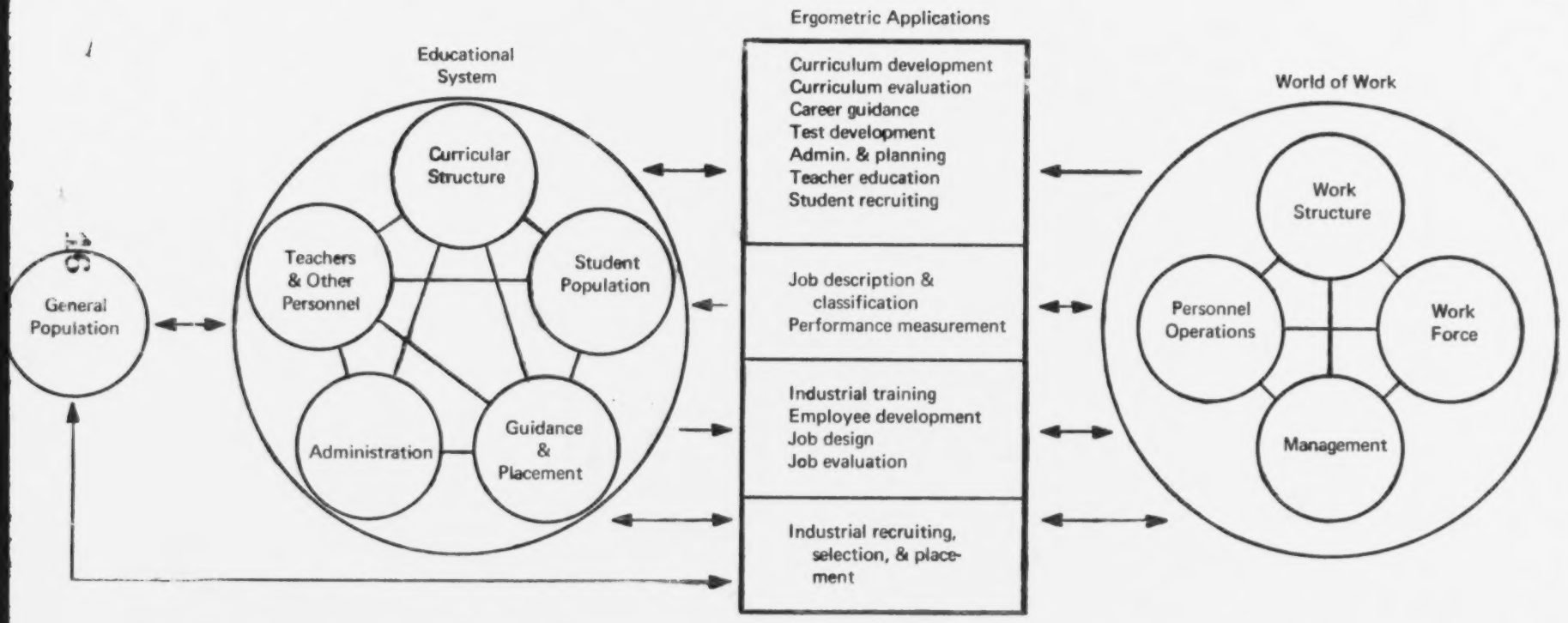


Fig. 1. A representation of the mediational function of ergometrics.

1969), the individual in his early years acquires general capabilities that are requisite to the subsequent acquisition of more specific and complex capabilities. (The reviewer would define a capability simply in terms of how well an individual can perform a specified class of tasks.) Eventually, through the successive acquisition and transfer of capabilities, the individual arrives at a point where he can perform the tasks in a particular work position.

If we accept the idea of a longitudinal progression of capabilities, then it would seem potentially profitable to start from the work domain in defining tasks to be learned in the educational setting. This practice is generally advocated in vocational and technical education, though it is often not systematically applied. It is not so uniformly acknowledged, however, in other educational settings. Curricula derived from the work domain could take a number of forms and could be applied at different educational levels. As one illustration, it might be feasible to develop occupationally-related curricula at different grade levels based on clusters containing occupations with similar work-dimension profiles; each occupational cluster would have an average work-dimension or task profile that could serve as a guide in determining the curricular structure and content for that cluster. Such an approach might be applicable in the development of occupational awareness and exploration curricula, curricula directed toward general vocational capabilities (Altman, 1966; Morrison, 1967), and more specific vocational and technical curricula. We could expect that the occupational clusters (and their descriptions) would be more general and inclusive the lower the grade level and the more general the curriculum.

The occupational-cluster approach is only one of a number of ways that information about the work domain could be translated into curricula. Another possibility would involve the development of curricula based upon systematically derived work dimensions representing classes of tasks (and conditions, e.g., the dimensions derived by Jeanneret & McCormick (1969) and Riccobono and Cunningham (1971a, 1971b). At the more advanced educational levels, it might prove feasible to present students with tasks closely approximating those in the world of work; at the earlier grade levels, it would be more reasonable to identify certain sets of basic task capabilities requisite to the performance of the more complex work-related tasks. The preceding examples are rather conventional; however, a comprehensive, well-structured, and empirically based taxonomy of human work could provide a framework for innovative changes in the educational system.

## Curriculum Evaluation

If ergometric procedures could be used in curriculum development, it would seem to follow that such procedures could also find application in curriculum evaluation. It might be feasible, for example, to perform comparative ergometric analyses between occupational curricula

and the occupations (or occupational clusters) toward which the curricula are directed. In this case, if a curriculum were a reasonably good simulation of the occupation for which it was intended, then we would expect some appreciable agreement between separate analysis of the curriculum and the occupation (i.e., the curriculum and occupation should share common elements or have similar work-dimension profiles. In addition to curriculum evaluation based on content analysis, an ergometric approach might also be taken in defining and quantifying performance dimensions, which in turn could serve as evaluation criteria. Such criterion dimensions could be quantified through performance rating procedures, as reported by Guion (1965) and Brumback and Vincent (1970); or tests could be constructed to measure performance on and reactions to these dimensions, e.g., Altman's (1966) vocational capability tests and D'Costa et al.'s Ohio Vocational Interest Survey (1970). Some tests that might be developed for use in evaluation, as well as individual assessment, are discussed in the following section.

## Test Development

Tests are frequently used to estimate the individual's work potential--i.e., his ability to perform specified classes of tasks and his tendency to approach or avoid classes of tasks, conditions, and outcomes. For this purpose, it would seem reasonable to develop tests around work dimensions and occupational and task clusters derived through ergometric procedures--e.g., the work dimensions derived by Jeanneret and McCormick (1969) and Riccobono and Cunningham (1971a, 1971b) and the job clusters derived by Sjogren, Schroeder, and Sahl (1967). The items in such tests would be paper-and-pencil (or equipment) simulations of work tasks (or task components) and conditions. Examples approximating this approach include: Altman's (1966) general vocational capability tests, based on hypothesized hardware-to-people continuum; the scales of the Ohio Vocational Interest Survey (D'Costa et al., 1970), based on the worker-trait groups established by the U. S. Employment Service (U. S. Department of Labor, 1965a); a recently developed interest inventory based upon the work of McCormick et al. (McCormick, Jeanneret, and Mecham, 1969b) in systematic job analysis;[3] and various occupational proficiency tests based on task enumeration and description. The ergometric approach could also be used in the development of an occupational awareness (or information) test.

A less obvious application of ergometrics might be found in the development of basic ability tests. In this connection, a comprehensive taxonomy that described and classified human work activities at different levels of specificity and complexity would presumably represent

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[3]R. C. Mecham, Utah State University, Logan, Utah; personal communication, July 2, 1971.

the entire gamut of human performance, and therefore might be used in the identification of classes of tasks for which basic ability tests could be developed. Furthermore, these basic abilities might be vertically linked to more complex, work-related capabilities (e.g., general vocational capabilities) such that it would be possible to specify the requisite basic abilities for classes of tasks at higher levels of development and complexity. (This possibility is discussed in greater detail on pp. 45-46.)

## Guidance, Placement, and Selection

If, as previously suggested, a comprehensive set of work dimensions could be established for purposes of job and occupational description, it might be possible to determine the human requirements of these various work dimensions in terms of attributes measured by standardized tests (i.e., attributes in the cognitive, psychomotor, and affective domains). It would then be possible to analyze a job in terms of the events that occur within it (i.e., in terms of a work-dimension profile) and, at the same time, derive as a by-product of this analysis an estimate of the extent to which the job requires certain measurable human attributes (i.e., derive an attribute-requirement profile for the job). This approach, which has been termed "synthetic validity" (Balma, 1959; Lawshe, 1952; McCormick, 1959), has been tested with encouraging results by E. J. McCormick and his associates (McCormick, Cunningham, and Thornton, 1967; Mecham and McCormick, 1969a). Alternatively, it is possible to estimate the human attribute requirements of jobs and occupations by rating them directly on the specified attributes. This approach has been applied with some success by the U. S. Employment Service (Trattner, Fine, and Kubis, 1955) and is currently under development at the American Institutes for Research as a means for determining the ability requirements of tasks (Theologus and Fleishman, 1969).

Regardless of the method used in obtaining attribute-requirement estimates for jobs and occupations, such estimates, if valid, could be employed in career guidance and in educational and job placement. In the guidance setting, the test score profiles of individuals could be compared with the attribute-requirement profiles of occupations or occupational clusters. Computerization would allow a large number of such comparisons, providing the individual with indices of congruence between his test profile and the requirement profiles of various occupations and occupational clusters (cf. Prediger, 1971a, b; Pucel, 1969; Rulon et al., 1967). If, in addition, translated work-dimension profiles for occupations and occupational clusters were made available to the counselee, such information might facilitate vocational exploration and decision-making. The USES worker-trait groups, groups of occupations with similar attribute requirements (U. S. Department of Labor, 1965c), might serve as an initial basis for a computerized vocational guidance and placement system. A profile-matching approach might also be used in educational and job placement, i.e., in screening individuals

and placing them in appropriate curricula and jobs. In this regard, the synthetic-validity approach to the identification of tests for selection purposes might meet the legal requirements that tests used in hiring and promotion be demonstrably related to performance on the job.[4] Furthermore, attribute-requirement estimates might be used in identifying occupations and designing curricula that match the characteristics of target populations (e.g., the average aptitude and need profiles of a specified population).

## Educational Planning

Adequate planning in occupational education requires information concerning both the nature of the occupational structure and manpower requirements for various categories within this structure. In this regard, projected manpower requirements (local, regional, and national), expressed in terms of work dimensions and occupational clusters, could be used as a basis for decisions concerning: the introduction and revision of curricula; teacher and student recruiting; the design, expansion, and remodeling of facilities; and resource allocation. National and regional manpower estimates for various categories in an ergometrically derived taxonomy might be obtained from the U. S. Census data, while local manpower information could be gathered through a survey procedure using a questionnaire based on the taxonomy. A work taxonomy could also serve as a framework for estimating human resources in relation to existing and projected manpower requirements, investigating the hypothesized shift in the distribution of demand for various human abilities (Venn, 1964), and identifying appropriate areas for the retraining of workers who are unemployed due to technological or economic changes.

## Job Design

While job design does not traditionally fall within the purview of education, it is reasonable that the educationist should participate in this activity, since most students eventually enter the labor force and since there seems to be a trend toward increased interaction between education and industry (e.g., Burkett, 1971; National School Public Relations Association, 1971). Accordingly, the educationist could provide information concerning the attributes and experiences of various segments of the student population, which in turn could be treated as constraints in job design. Jobs could be modified or designed for better compatibility with the abilities, experiences,

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[4]Supreme Court of the United States, Willie S. Griggs et al., Petitioners, v. Duke Power Company, No. 124, March 8, 1971; Civil Rights Act of 1964, Title VII, section 713.

interests, and needs of target populations, and for homogeneity in ability requirements (Tiffin and McCormick, 1965). Just as technological considerations place explicit constraints on job design, so should considerations of the characteristics and limitations of the human component in jobs.

## Research

A comprehensive set of ergometrically derived work dimensions could also provide a basis for comparison in applied research and development; such dimensions could be used in determining degrees of similarity among jobs or tasks across studies. In addition, it is at least conceivable that ergometrics could contribute to task design in basic research. If, for example, the previously mentioned multi-level taxonomy of work were developed, it might then be possible to design laboratory tasks that could be linked to more complex work-related tasks, thereby facilitating the interpretation of basic research findings for purposes of applied research and development. The work in task description and classification currently under way at the American Institutes for Research (Chambers, 1969; Farina, 1969; Farina and Wheaton, 1969; Wheaton, 1968) might ultimately lend itself to this purpose.

## STUDIES OF JOB DIMENSIONS AND COMMONALITIES

As noted previously, the most systematic approach to occupational description and classification involves the use of a common set of work elements or dimensions on which a variety of jobs can be profiled (McCormick, 1964; McCormick, Cunningham, and Thornton, 1967; McCormick, Jeanneret, and Mecham, 1969b). Accordingly, the following review summarizes a number of studies dealing with the definition of work dimensions and the use of such dimensions in establishing job commonalities. The review has been divided into three major sections, based upon three broad genres of job and occupational characteristics that have been dealt with in previous studies: (1) basic human attribute requirements (e.g., aptitude requirements); (2) skill and knowledge requirements; and (3) activity or task components. Although there were a few instances where it was difficult to assign a study to one of the above categories of job variables, this usually occurred not because the variables fell outside this classification scheme, but because the study in question dealt with more than one of the categories. In such cases, an assignment was made to the one category that seemed to best represent the major orientation of the study.[5] Most of the studies reviewed have treated jobs and occupations as the basic units of interest; however, a few of these studies have focused on tasks as the units of analysis.

### Some Definitions

Although terms such as "task," "job," and "occupation" have been used liberally in the preceding pages, they have not been explicitly defined. Some definitions are presented here as a glossary to the review.

A task has been defined by several writers as a set of related activities which occur in sequence or closely together in time and which are directed toward a common goal, or outcome (McCormick and Tombrink, 1960; Miller, 1956; Morsh, Madden, and Christal, 1961; U. S. Department of Labor, 1965a). A statement of a simple task familiar to the instrumental-conditioning psychologist might read as follows: "Within 3.5 seconds of light stimulus onset, depress the bar with a minimum force of 25 grams." Some abbreviated examples of more complex tasks include: inspect engine, park vehicle, set up machine, operate machine,

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[5] Other relevant reviews can be found in two reports dealing with task description and classification published by the American Institutes for Research (Farina, 1969; Wheaton, 1968), in a recent report by Sjogren (1971) on occupational adaptability, and in an article on job analysis just published by Prien and Ronan (1971).

inspect work piece, file reports and correspondence, tabulate and post data in record books, make out accident report, bathe patient, flowchart a problem, etc. (Altman, 1966; U. S. Department of Labor, 1965a). It should be noted, however, that tasks are typically defined in more detailed form for job-analysis purposes; systematic procedures for preparing task statements (and statements of the component activities in tasks) are described in several sources (e.g., Morsh, Madden, and Christal, 1961; Mager, 1962; Miller, 1962; U. S. Department of Labor, 1965a). In addition to the preceding definition of a task, a recent approach treats the task as a set of external conditions or constraints imposed upon the performer, independent of his behavior (Hackman, 1968; Stolurow, 1964a, 1964b; Wheaton, 1968). Although this latter conception has some merit, the definition of a task as a set of related activities will obtain for purposes of this review, since this definition applies to most studies of task commonalities among jobs. As Bennett (1971) has recently noted, one of the problems in defining the concept of "task" lies in the difficulty in establishing a level of inclusiveness (or complexity) for this unit of work. The reviewer has attempted to deal with this question--albeit inadequately--by citing the foregoing examples of tasks.

A position is usually defined as a set of tasks performed by an individual worker (McCormick and Tombrink, 1960; Shartle, 1959; U. S. Department of Labor, 1965a); and a job, in turn, can be defined as a set of similar positions (i.e., positions composed of similar major tasks) existing within the same establishment (Shartle, 1959). Although Shartle's definition of a job conflicts with that used in the Dictionary of Occupational Titles (U. S. Department of Labor, 1965a, 1965b), his definition has been adopted for purposes of this review because it permits a reasonably clear distinction between the concepts of "job" and "occupation." Shartle defines an occupation as a set of similar jobs across different establishments, a definition that the DOT attaches to the term "job." Since the minimum degree of similarity among jobs constituting an occupation--and hence the level of generality or inclusiveness of an occupation--is an arbitrary matter, the reviewer (following Shartle) will cite the titles and definitions in Volume I of the DOT as examples, or benchmarks, of the level of generality at which occupations are defined. Included in the DOT are occupations such as material scheduler (aircraft mfg.), surveyor, sports editor, passenger car conductor, calculating machine operator, hair stylist, nurse aide, furnace operator (found., iron and steel), and chipping machine operator (slaught. and meat pack.). For the sake of brevity, the term "job" will be applied hereafter (as previously) to general cases covering positions, jobs, and occupations.

Finally, an occupational cluster is defined as a set of similar occupations. The level of generality implied by the term "occupational cluster" is also an arbitrary matter and one that must be determined by the purpose which the cluster is intended to serve. Thus, certain types of vocational and technical curricula might require rather narrow occupational clusters; curricula designed to teach general vocational capabilities could be based upon considerably broader clusters; and occupational awareness and exploration curricula could be developed for quite general clusters, or occupational families.

## Basic Attribute Requirements of Jobs

The term "attribute," as used in this review, refers to a relatively stable behavioral predisposition, represented by a dimension on which individuals can be measured. Attributes might be classified into two broad categories: (1) abilities, such as those defined by Thurstone (1938), Guilford (1967, 1971), and Fleishman (1964); and (2) personality traits, such as interests, temperaments, and needs. Operationally, abilities are defined in terms of how well an individual performs a specified class of tasks, i.e., the number of items correctly answered on an ability test. Tests (tasks) with substantial intercorrelations, or substantial loadings on the same factor, are assumed to measure the same ability. A conceptual definition of ability has been proposed by Ferguson (1956), as follows:

> Certain aspects of the state of the organism obtain a crude stability or invariance [through learning] and are less susceptible than others to modification through continuing behavior and other factors over limited ranges of time. These postulationally, are invariants of the state of the organism, which in turn are functionally related to certain invariants in particular observable behaviors. What we conventionally regard as the abilities of man are among these invariants. (p. 126)

Personality traits can be similarly defined. For example, affective attributes such as interests, needs, and attitudes, might be conceived as tendencies to approach or avoid specified classes of tasks, conditions, or outcomes--i.e., as approach-avoidance dimensions. In regard to such attributes, Ferguson suggests that "Characteristics of personality, attitudes, and the like can be viewed as attributes of behavior which have attained some stability through a lengthy learning process." (p. 127)

This section of the review contains summaries of several studies that have employed human attribute dimensions as job descriptors. The summaries are followed by a brief discussion of these studies and of the attribute-requirement approach to occupational description and classification.

An early attempt to derive dimensions based upon attribute ratings of occupations was reported by Jaspen (1949). In this study, 275 occupations were rated on the extent to which they required 45 human traits. After eliminating 25 traits which occurred infrequently in the 275 occupations, the investigator intercorrelated the 20 remaining trait items, along with three items dealing with tools, knowledge of graphic instruction, and skill level. A factor analysis of the resulting 23 X 23 correlation matrix yielded six interpretable dimensions: Strength, Intelligence, Inspection, Working Conditions, Manual Dexterity, and Mechanical Information. It was suggested that such factors might be appropriate

". . . for the purpose of establishing a limited number (less than fifty) of occupational fields distinguished on the basis or worker characteristics for use in counseling . . . ." (p. 427)

In a study somewhat similar to Jaspen's, McCormick, Finn, and Scheips (1957) performed a factor analysis of 44 variables using a sample of 4000 jobs. Data for this analysis were obtained from the U. S. Employment Service and included ratings of the jobs on aptitudes, temperaments, interests, physical capacities, and working conditions (U. S. Department of Labor, 1956). The analysis yielded seven factors: (1) Mental and Educational Development versus Adaptability to Routine, (2) Adaptability to Precision Operation, (3) Body Agility, (4) Artistic Ability and Aesthetic Appreciation, (5) Manual Art Ability, (6) Personal Contact Ability versus Adaptability to Routine, and (7) Heavy Manual Work versus Clerical Ability. Following the factor analysis, factor scores were derived for each of the 4000 jobs by the Wherry-Doolittle test selection method; six sets of factor scores were then dichotomized into "High" and "Low" categories, and scores for a seventh factor were categorized as "High," "Medium," and "Low." All possible permutations of these factor-score levels resulted in 192 unique combinations, which the investigators referred to as "patterns." It was found, however, that most of the jobs fell into a relatively small number of these patterns. Thus, 12 patterns accounted for 60 percent of the jobs in the sample, 20 patterns for 75 percent of the jobs, and 33 patterns for 80 percent of the jobs. The investigators were encouraged by these findings and concluded that ". . . jobs collectively do not scatter themselves to the four winds as far as job requirements are concerned, but rather tend to fall into certain predominant molds." (p. 363)

Another investigation utilizing the USES trait ratings was conducted by Orr (1960). In this study, "Distance (D) Measures" based on nine USES aptitude ratings were obtained between pairs of jobs, such that a large D-score represented a large difference between jobs in terms of aptitude ratings. The D-scores for two independent samples of jobs were subjected to separate cluster analyses which yielded six job clusters for each sample; a subsequent matching of each cluster in one sample with a cluster in the other sample produced in six pairs of comparable clusters. Next, each job in a third sample was assigned to one of the clusters from each of the two original samples on the basis of the job's D-scores from the various cluster centroids. Based on the finding that 75 percent of the jobs in the third sample fell into matched clusters, Orr concluded that the clustering technique used in this study was reasonably consistent and workable.

Trattner, Fine, and Kubis (1955) have also done research using the USES trait ratings of jobs. In this study, 10 jobs were rated on 10 aptitudes by two groups of job analysts: one group rated the jobs on the basis of direct observation, while the other group used written job descriptions. A correlation between these two sets of ratings showed substantial consistency in results obtained from the two sources of job information. In addition to the foregoing analysis, the investigators

correlated the aptitude ratings of the 10 jobs with the average GATB aptitude test scores of workers in these jobs. The trait ratings were found to correlate .44 and .58 with actual test scores, indicating ". . . a rather satisfactory degree of . . . consistency with objective test data."

Another effort to establish the attribute requirements of jobs has been reported by Ernest S. Primoff and his associates (Primoff, 1953, 1955, 1957, 1959; Wherry, 1955; Maslow, 1958), who have developed a method of indirectly determining test validities. This method, the "J-coefficient technique," involves the following steps:

(1) First, a group of raters analyzes a job in terms of a list of defined human attributes; each rater judges the extent to which each of the specified attributes is necessary for successful performance on the job. The ratings on a given attribute are then combined, yielding an estimate of the extent to which the attribute in question is necessary for performance of the job. A score is thus obtained for each of the attributes.

(2) Next, attribute weights for a specified battery of tests are obtained from a table. These test values, or "Beta weights," are estimates of the extent to which the attributes contribute to performance on the various tests; that is, each Beta weight estimates the unique contribution which a particular attribute makes toward the prediction of scores on the test in question. The Beta weights, originally based on the judgment of a group of psychometrists, are revised as actual test validities are obtained.

(3) A J-coefficient is then computed for each test in the battery by applying a formula to the attribute weights of the job and the Beta weights of the test. The resulting coefficient is an estimate of the Pearsonian correlation between scores on the test and performance on the job.

Wherry (1955) reported a study of the job of Printer Assistant (Bureau of Engraving and Printing), in which the J-coefficients for five tests were correlated with the actual validity coefficients. With a sample of 54 workers, the correlation was .55; in a follow-up study involving a sample of 135 new workers, it was .93. Wherry concluded that "This technique . . . does have some experimental evidence to indicate that it does actually work . . . ." (p.5) Thus, both the research of Primoff et al. and the study by Trattner, Fine, and Kubis have demonstrated some degree of validity in direct ratings of the attribute requirements of jobs.

Trait requirements of jobs were also investigated in two related studies conducted under the aegis of the Air Force Personnel and Training Research Center at Lackland Air Force Base. In the first study, Norris (1956) compiled a list of 170 human trait names and definitions which he had gathered from various sources in the literature. He then

assigned a group of job analysts the task of making five-point ratings of 150 Air Force jobs on each of the 170 traits. A factor analysis was performed on the ratings of the 130 most reliable traits, yielding 25 factors, 11 of which were identified as meaningful. Seven additional trait variables were identified which had appreciable variance not accounted for by the eleven factors. Thus, a total of 18 variables was proposed as providing ". . . a useful framework for describing the requirements of Air Force enlisted jobs."

In a sequel to the Norris study, Thorndike et al. (1957) constructed activity items for each of 14 trait dimensions. The trait dimensions, selected from those identified by Norris, were represented by from 7 to 20 items each; a dimension score was based on the summed scores of the activity items representing that dimension. The resulting Job Activities Blank was administered to 963 men in 25 Air Force jobs, who were instructed to rate each activity on a five-point frequency scale ranging from "A--never do it" to "E--do it very often . . . ." A matrix of intercorrelations based on the 14 sets of dimension scores showed some surprisingly large (and unwelcome) correlations among these presumably independent dimensions; a principal components factor analysis reduced the 14 oblique dimensions to eight orthogonal factors. The next step in this project involved two separate cluster analyses of the 25 jobs based on a D-score similar to that used in Orr's study. In the first cluster analysis, the D-scores were computed from 13 of the oblique trait dimensions; in the second analysis, D-scores were based upon five of the orthogonal factors. The correlation between the two sets of D-scores was .91, indicating rather close agreement between the two methods of measuring job similarity. The investigators concluded that the relatively high correlations among the trait dimensions would reduce their effectiveness in measuring job requirements and clustering jobs.

A recent effort to group occupations in terms of similar attribute requirements was reported by Ghiselli (1966). In this study, validity data for 21 occupations were obtained from various sources in the literature. These data were restricted to validity coefficients for ability tests, based on proficiency criteria and samples of at least 100 persons. For purposes of data analysis, the ability tests were grouped into four categories: intellectual abilities, perceptual accuracy, motor abilities, and spatial-mechanical abilities. The validity coefficients (transformed to Fisher's $z$'s) were then averaged for each occupation within each of the four ability categories; this resulted in a validity profile for each occupation on four ability dimensions. These data, in turn, provided a basis for intercorrelating the four ability dimensions; and intercorrelation between two ability dimensions was computed from the average validity coefficients for the 21 occupations. Because the intellectual and perceptual dimensions correlated .86, these two dimensions were combined by averaging their validity coefficients within each occupation. The average validity coefficients for the remaining three ability dimensions were then used to compute distances between all possible pairs of the 21 occupations, and the resulting distance matrix served as a basis for

deriving two major clusters and eight subclusters of occupations. Two characteristics of these clusters are noted in the following paragraph:

> Two properties of the organization and grouping of jobs seem clear. First of all, in terms of their requirements jobs are not organized into clear-cut and separate groups. Rather there is a continuous variation among jobs, and they form clusters which do not have distinct boundaries. Second, jobs which superficially appear to be similar in terms of nature of work may have quite different ability requirements, and jobs which appear to be quite different may have very similar requirements. (Ghiselli, 1966, p. 111)

Ghiselli concluded that although there is considerable variation in the validity of tests across different types of occupations, it is nevertheless possible to systematically describe the human requirements of the various occupations comprising the world of work.

With the exception of the studies by Thorndike et al. (1957) and Ghiselli (1966), the basic data of the research reviewed in this section were job analysts' ratings of the extent to which various human attributes were required in jobs. Although the assumption that judges are capable of estimating the attribute requirements of jobs is not without some empirical support (Trattner, Fine, and Kubis, 1955; Primoff, 1959), it is, nevertheless, one that seems rather demanding of human capabilities. Most descriptions of human attributes are rather abstract in comparison to other types of descriptions (such as activity or task statements) and, for this reason, should be relatively difficult to rate.[6] This was, in fact, the supposition of the study by Thorndike et al., in which trait-requirement scores were derived indirectly through job activity ratings. Furthermore, the generality and abstractness of attribute definitions limit their usefulness for curriculum development purposes: it would be difficult to translate an attribute-requirement profile for a job or occupation into curricular content, and a cluster of jobs with similar attribute-requirement profiles would not necessarily be homogeneous in terms of knowledge and skill requirements. The approach taken by Ghiselli, though methodologically sound, would be infeasible for jobs lacking sizable numbers of employees and prohibitively expensive and time-consuming if applied to a large number of jobs.

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[6] Although the reviewer has no direct evidence to support this statement, Paivio (1963) has found that words classified as abstract are not as easily learned in paired associate tasks as words classified as concrete. Furthermore, in an unpublished study by the reviewer and his associates, jobs were more reliably rated on physical activity statements than on mental activity statements (which tend to be somewhat abstract).

Despite the limitations of attribute ratings as job descriptors, such data, if reliable and valid, could be used for any of the previously mentioned educational activities requiring estimates of the human attribute requirements of jobs. The trait ratings of the U. S. Employment Service are currently available for this purpose, and a set of ability rating scales under development at the American Institutes for Research (Theologus and Fleishman, 1969) should provide a sound procedure for directly estimating the ability requirements of tasks and jobs. An indirect approach to estimating the attribute requirements of jobs (synthetic validity) will be discussed later in this review.

## Knowledge and Skill Requirements of Jobs

Like definitions of basic attributes, or traits, knowledge and skill definitions refer to hypothetical conditions within the organism. The expression "knowledge of . . ." usually refers to some specified class of information which is stored within the individual and which he can recall (and perhaps apply) under appropriate circumstances (English and English, 1958). The term "skill" refers to an individual's level of proficiency on a specific set of tasks, e.g., typing, driving an automobile, playing bridge, drafting, etc. (Fleishman, 1967a, 1967b). Knowledge and skill definitions are distinguishable from basic attribute definitions in being more specific and content oriented than attribute definitions. Thus, a knowledge statement might read "[knowledge of] fuel systems or internal combustion engines and the functions of parts," (Schill and Arnold, 1965, p. 104) whereas an attribute statement might read "ability to reason abstractly using quantitative concepts and symbols." (Mecham and McCormick, 1969b)

One of the first systematic attempts to group jobs on the basis of knowledge and skill ratings was reported by Coombs and Satter (1949). In this study, 54 jobs in a midwestern paper mill were first rated on the presence or absence of 104 skill and knowledge elements, and then intercorrelated on the basis of numbers of common elements. The resulting intercorrelation matrix was subsequently reduced to a 20 X 20 matrix based on those 20 jobs having the lowest sums of correlations with other jobs. A factor analysis of the correlation matrix yielded the following job factors: Self-Responsible Jobs; Routine, Entry Occupations; Skilled Machine Operation Jobs; Clerical Jobs; and a general factor loading on every occupation in the analysis. The investigators carefully noted the sampling limitations of their study and also pointed out that job analyses should be designed for the particular purposes that job groups are intended to serve.

More recently, Chalupsky (1962) constructed two checklists for job-analysis purposes, one listing 58 clerical knowledges (e.g., knowledge of writing, knowledge of operating an adding machine, etc.) and the other consisting of 33 clerical functions (e.g., analyzes, compiles, plans, and translates). The two checklists were subsequently used

in analyzing a sample of 192 clerical occupations (from written descriptions), with the resulting data providing a basis for separate factor analyses of the items in each checklist. Of the six factors obtained from the knowledge checklist, four were judged to have counterparts among the five factors emerging from the function checklist. These four common factors were named Inventory and Stockkeeping, Supervision, Computation and Bookkeeping, and Communications and Public Relations. The two remaining factors from the knowledge checklist were labeled Stenography-Typing and General Clerical; a fifth factor from the function checklist appeared to encompass both of the preceding knowledge factors. Chalupsky drew three conclusions from his results: (1) there is a strong similarity in the factors emerging from the two different sets of variables; (2) these factors represent meaningful dimensions of clerical occupations; and (3) the application of factor analysis to job-analysis checklists is a useful procedure for identifying the common denominators of occupations.

A study conducted by Courtney (1962) involved an attempt to determine common knowledge requirements for three agriculturally-related occupations: farmer, farm real estate broker, and farm grain elevator operator-manager. For this purpose, the investigator constructed a questionnaire consisting of 148 task statements and a five-point knowledge scale. The questionnaire was administered to 120 incumbents (40 in each of the three occupations) with instructions to rate each statement on the extent to which knowledge of the task in question was required by the incumbent's position. An analysis of variance was then performed for each task statement in order to determine whether the three occupations differed in their knowledge requirements for that task. Significant F ratios were obtained in 116 of the 148 ANOVA's; the 32 remaining task statements, whose F ratios were not significant, were identified as representing common knowledge requirements across the three occupations. In addition to overall tests of significance, individual comparisons were made between the three pairs of occupations for each of the 148 statements. These latter analyses produced 89 common requirements (i.e., nonsignificant differences) between the occupations of farmer and grain elevator operator-manager, 58 between farmer and farm real estate broker, and 106 between farm real estate broker and farm grain elevator operator-manager. (It was noted, however, that most of the 106 statements in the last comparison were scored low for both occupations.) In his conclusions, Courtney suggested that his results might ". . . be used as guides to curriculum emphasis for teachers of vocational agriculture . . . ." (p. 53)

A series of studies conducted at Washington State University (Rahmlow, 1967) has also dealt with the problem of identifying knowledges common to occupations within specified areas. In one of these studies (Mills, 1966), the definitions of eight principal tasks of electronics technicians were derived from the literature and discussions with technicians and employers. Additionally, 637 knowledge items were identified ". . . by review of the textbooks, courses of study, the suggested curriculum guide prepared by the United States Office of Education,

instructors, and technicians themselves." (p. 12) The basic data consisted of responses from 154 technicians in various industries to a questionnaire which instructed the respondent to first check one of the eight principal tasks which best described his work and, next, to check each knowledge item which his work required. A frequency count was subsequently made to determine which knowledge items were common to several principal tasks. From this analysis it was found that 84 of the 637 knowledges were judged essential in six or more of the principal tasks. On the basis of this finding, Mills concluded that introductory electronics courses should be designed to include these 84 frequently required knowledges. Other studies at Washington State University have sought by similar methods to identify common knowledge and task requirements within the building trades (Bakamis et al., 1966), farm operations occupations (Long, 1968), and health occupations (Wallenstein, 1968).

In a study reported by Schill and Arnold (1965), technicians and managers were asked to rate the extent to which 99 knowledge and skill items described the requirements of various technician occupations sampled from six technological areas. The ratings were divided into three categories: (1) items closely related to successful work performance, (2) items somewhat related to successful work performance, and (3) items unrelated to successful performance of the occupation in question. The results showed 13 items to be relevant to all six categories of technicians and 42 items to have little or no relevance to any of the technologies; the remaining 44 items were found to have varying degrees of relevance to one or more of the technological areas. Based on these findings, the authors recommended a core program of required knowledges for technician training and identified other knowledges specific to the various technologies.

Dillon and Horner (1968) have recently reported a large study in which 1315 persons, employed under 384 different job titles in the state of Nebraska, completed a questionnaire which listed 144 job knowledges, activities, and duties. Of the 144 different items, 20 knowledges and 23 activities or duties were identified by 33 percent or more of the workers as being required in their positions; two knowledges and nine activities or duties were checked by 50 percent or more of the workers. The investigators view these ". . . groups of activities and areas of knowledge . . . as common components and as a base for vocational course construction." (p. 55)

In a project currently under way, Gilpatrick (1970) has applied 17 skill-dimension scales in the analysis of 138 tasks performed in three medically related positions. The incumbents in these positions held the titles of Nurse Aide, Licensed Practical Nurse, and Senior Physical Therapist. The 17 skill scales fell into six categories: (1) manual, (2) interpersonal, (3) information-related, (4) language, (5) decision making, and (6) error consequences. Trained job analysts rated each task from direct observation and interviews with the incumbents. A factor analysis of the 17 skill dimensions, based on ratings

of the 138 tasks, produced four interpretable factors dealing with the following types of skills: (1) human interaction and decision making, (2) physical health and ambulation, (3) use of data and information and reading-writing skills, and (4) object manipulation related to physical therapy. In addition to the factor analysis of skill dimensions, an inverse factor analysis was performed treating tasks as variables and the task dimensions as observations. In this way, the resulting factors could be interpreted as task clusters, with factor loadings serving as indices of the extent to which various tasks belonged to a specified cluster. Four task factors were revealed in this analysis: (1) a human interaction factor dealing with the instruction and counseling of patients and students, (2) a locomotive and guiding factor dealing with tasks involving helping and teaching patients to ambulate, (3) a factor involving reading work orders and writing therapy programs and performance evaluations, and (4) a manipulation factor pertaining to classes of tasks such as physical therapy treatments. It was observed that the highest loading tasks on all four factors belonged to the highest level position (Senior Physical Therapist), suggesting a task hierarchy within each factor. Gilpatrick noted that although these results must be considered tentative because of restrictions on the sample of positions and tasks, the meaningfulness of the factors is encouraging for future efforts to identify task clusters.

The basic data of the studies reviewed in this section were, for the most part, obtained from human judgments of the extent to which various knowledges and skills are required in the performance of specified tasks or jobs. Such judgments are probably less difficult than judgments of basic human attribute requirements, since knowledge and skill definitions are usually more directly relatable to observable events in the job than are attribute definitions; that is, knowledge and skill statements are more specific and concrete than attribute statements. The task of rating jobs in terms of knowledge and skill requirements does, nevertheless, require some inference on the part of the rater concerning the internal state of the worker, since the concepts of "knowledge" and "skill" are directed as much toward the implicit state as the observable act. Thus, the use of knowledge and skill statements in job analysis is subject to the same criticisms that writers such as Mager (1962) and DeCecco (1968) have directed against implicit (versus explicit or behavioral) instructional objectives. It should be noted, however, that two of the studies reviewed in this section (Chalupsky, 1962; Dillon and Horner, 1968) used activity as well as knowledge and skill statements, and that a third study (Courtney, 1962) used task statements in conjunction with a knowledge scale. In addition, some of the statements in Mills' (1966) study, though generated within a knowledge framework, had activity connotations.

## Activity Components of Jobs

The studies reviewed under this heading have dealt with activity or task commonalities among jobs. The term "task" was defined earlier

(p. 26); "activity" is a more general term which varies in its usage from forms of behavior more molecular than typical work tasks (e.g., finger manipulation) to classes of behavior more inclusive than tasks (e.g., instructing). Two types of studies will be summarized: (1) those dealing with activity or task statements applicable to restricted ranges of jobs and (2) those dealing with statements applicable to jobs in general.

## Activity Statements Applicable to Restricted Ranges of Jobs

A number of investigators have analyzed restricted ranges of jobs using sets of activity or task statements. In one such study, Thomas (1952) applied a 139-item checklist of clerical tasks in the analysis of 112 office positions. Incumbents in these positions and their immediate supervisors were asked to check each task which occurred in the incumbent's position. Only the 79 items which were checked by 20 or more respondents were retained for further analysis. Phi coefficients were then computed between all pairs of the surviving items, and the resulting correlation matrix was subjected to a cluster analysis. This analysis yielded eight clusters of clerical tasks, which were named as follows: (1) Typing, (2) Listing and Compilation, (3) Communication, (4) Planning and Supervision, (5) Filing, (6) Stock Handling, (7) Routine Clerical, and (8) Calculation. In his article, Thomas cautioned that because of the limitations of his sample, these clusters might not adequately represent the activity dimensions in the general population of office jobs.

Another study of clerical activities was conducted by Lawshe and Steinberg (1955), who used a 139-item checklist of clerical tasks (the Job Description Checklist) and a seven-section clerical test (the Purdue Clerical Adaptability Test) in an attempt to establish test validities through job analysis. Prior to this study, the 139 clerical tasks had been rated on the extent to which the seven subtest characteristics were essential to their performance; thus, each of the clerical subtests could be classified as either "critical" or "noncritical" in terms of each of the 139 checklist operations. The sample in the study consisted of 262 clerical positions in 12 different companies. Supervisors in these companies were asked to choose the five operations from the checklist which best characterized each of the positions in question (i.e., five "core" operations were designated for each of the 262 positions). In addition, workers in these 262 positions were administered the Purdue Clerical Adaptability Test. The authors had hypothesized that workers whose positions involved a substantial number of critical requirements on a subtest characteristic would score higher on that test than workers whose positions had fewer of these requirements. Thus, for each of the seven subtests, the 262 positions in the sample were classified into three groups as follows: (1) those positions having four or five tasks with critical requirements on the subtest characteristics, (2) those having two or three tasks with these requirements, and (3) those having none or one. The percentage of workers exceeding the median score of

the test in question was then determined for each of the three categories, under each of the seven subtest characteristics; a chi-square test was conducted for each of the seven subtests to determine whether the three categories differed significantly in percentages of workers exceeding the median test score. Significant chi-square values were obtained for four of the seven subtests (spelling, arithmetic computation,vocabulary, and arithmetic reasoning), leading the investigators to conclude that "Based upon this study, it would seem that we have made progress toward 'synthetically' determining the test requirements for a particular job." (p. 297)

In a study of entry-level occupations, Maley (1966) compiled a list of 13 possible occupational clusters based on the following criteria:

> The occupational cluster should:
>
> 1. Be in the area of vocational industrial education.
>
> 2. Include occupations that are related on the basis of similar processes, materials, and products.
>
> 3. Be broad enough to include occupations with a wide variety of skills and knowledges.
>
> 4. Involve occupations that require not more than a high school education and/or two years beyond high school.
>
> 5. Provide the opportunity for mobility on a geographical and occupational basis. (p. 45)

The list of 13 occupational clusters was subsequently reduced to the following three clusters: (1) metal forming and fabrication, (2) construction, and (3) electro-mechanical installation and repair. Based upon several criteria, a sample of occupations belonging to each of the forenamed clusters was then selected, and a list of job-entry task statements was compiled for each occupation. Next, each task statement was examined to determine what areas of "human [psychomotor and cognitive] requirement (communication, measurement, mathematics, science, skills, and information) were . . . required [for] the performance or each task." (p. 73) A behavioral statement (e.g., "reading blueprints to determine size of parts") was prepared for each specific human requirement of a task, and all such statements for a given occupation were ". . . compared with the behavioral statements in similar areas of human requirements in other occupations within the cluster . . . ." (p. 74) Finally, a frequency count was made of the number of common behavioral statements occurring within an occupational cluster for each area of human requirement. The identified common areas of human requirement and the task statements were subsequently used in the development of course outlines, achievement test items, and evaluation criteria for the three occupational clusters. At the time this study was reported, Maley and his associates were planning a pilot program

designed to implement his research findings at the secondary school level.

Several studies in the previously cited research program at Washington State University (see pp. 24-25) have dealt with task commonalities within restricted categories of occupations. These studies, which will not be described here, have included efforts to establish commonalities within the building trades (Bakamis et al., 1966), child care occupations (Rahmlow and Cavanagh, 1966), food service occupations (Rahmlow, Johnson, and Cavanagh, 1966), office occupations (Perkins, Byrd, and Roley, 1968), and merchandising occupations (Ertel, 1968). Similar work is currently under way at the Ohio State University in the following occupational areas: secretarial, data processing, automotive mechanics, and community college instruction (Center for Vocational and Technical Education, 1970a, b, c, d).[7] The Ohio State studies are employing adaptations of the task-inventory procedures developed by the U. S. Air Force (Archer, 1966; Morsh, 1969; Morsh and Archer, 1967).

The Air Force has invested considerable effort in identifying job commonalities among jobs based on task statements. In one Air Force study (Morsh, 1965), 1647 airmen in 11 personnel-career specialties completed a 260-item task inventory under instructions to (1) check the tasks that were relevant to their positions and (2) rate these tasks on a five-point scale of time required. The time-spent ratings of each incumbent were converted to percentages by dividing the rating on each task by the total of all of the incumbent's time-spent ratings and multiplying the quotient by 100. From these data, it was possible to compute an index between each pair of incumbents of the overlap in percentage of time spent on all tasks. This index was treated as a measure of similarity between positions in a subsequent hierarchical clustering analysis of the 1647 cases. The analysis, which utilized a computerized hierarchical grouping program developed by Ward (1961), resulted in 34 "job types" containing from 8 to 201 positions. For each job type, an average description was generated consisting of a list of the average times spent on the various tasks by members of that group. An examination of the results showed that the memberships in a number of the job types cut across commands, grades, and Air Force classification specialties. It was also reported that ". . . the number and kinds of tasks performed and the time spent on them vary with the incumbent's job type, grade, and experience." (p. 99)

The last three studies to be described in this section have dealt with managerial and professional positions. In one of these studies, Hemphill (1959) derived 10 dimensions underlying 93 executive positions. The 93 positions were drawn from the beginning, middle, and upper management levels (excluding first-line supervision), and from the following

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[7] S. D. Brocher and F. C. Pratzner, Center for Vocational and Technical Education, Ohio State University, personal communication, September 9, 1971.

functional areas: research and development, sales, manufacturing, general administration, and industrial relations. Each manager completed a questionnaire containing 575 "position elements" by rating each element on the extent to which it applied to his position. The position elements fell into four categories: (1) position activities (239 elements), (2) position responsibilities (189 elements), (3) position demands and restrictions (84 elements), and (4) position characteristics (63 elements). The resulting data were subjected to an inverse interbattery factor analysis (Tucker, 1958) which treated the 93 positions as variables and the 575 questionnaire items as observations. The analysis yielded 10 factors, labeled as follows: (1) Staff service; (2) Supervision of work; (3) Internal business control; (4) Technical aspects of products and markets; (5) Human, community, and social affairs; (6) Long-range planning; (7) Exercise of broad power and authority; (8) Business reputation; (9) Personal demands; and (10) Preservation of assets. Hemphill suggests several areas of application for his 10 dimensions, including: promotion, organizational analysis, job rotation, performance appraisal, and salary administration.

Subsequent to the Hemphill study, Prien (1963) developed a questionnaire consisting of statements describing general functions of first-line supervisory positions (e.g., "explain and discuss problems with staff personnel"). Questionnaire responses were obtained from 24 foremen and their supervisory executives in one company, and the resulting data were subjected to an inverse factor analysis--i.e., the 24 foremen's positions were intercorrelated based upon questionnaire-response profiles, and the resulting correlation matrix was factor analyzed. The seven factors emerging from this analysis were named as follows: (1) Manufacturing process supervision; (2) Manufacturing process administration; (3) Employee supervision; (4) Manpower coordination and administration; (5) Employee contact and communications; (6) Work organization, planning, and preparation; and (7) Union-Management relations. A second-order factor analysis, utilizing factor scores obtained from the first analysis, produced two factors, a "work oriented" factor and an "employee-oriented" factor. Prien judged five of his first-order factors to be similar to factors obtained by Hemphill (1959), and concluded that the study provided ". . . support for the development of procedures to describe position functions of an intangible nature." (p. 14)

In a recent study by Brumback and Vincent (1970), a questionnaire containing 196 duty descriptions was administered to 3,719 Commission Corps Officers in the U. S. Public Health Service. For the purpose of instrument development, the investigators adopted McCormick and Tombrink's (1960) definition of a duty as a major part of a position and a composite of related tasks. A respondent rated each duty in terms of its significance to his position. A principal components analysis of the 196 questionnaire items yielded 26 clearly defined factors which, according to the investigators, will provide a basis for developing a performance rating instrument.

The studies reviewed in this section have dealt with commonalities within limited categories of jobs. In a sense, such categories are

rationally defined clusters: groups of jobs or occupations that are considered, prima facie, to have something in common. The task of the investigator in these studies was to determine what these commonalities were. If an a priori occupational category, or cluster, is well selected and if a comprehensive set of task statements is initially compiled for the cluster, the subsequently identified commonalities and dimensions can be useful for educational or training purposes. Task statements developed for limited classes of jobs have the advantage of being rather specific and, for this reason, should provide the degree of resolution necessary for the development of focused vocational and technical curricula. Furthermore, since task statements refer to specific and concrete behaviors and outcomes, they should be relatively easy to rate. However, task statements developed for a restricted category of jobs are usually limited in their applicability to those jobs and, consequently, are not very useful for making comparisons outside the specified category.

The Air Force's task-inventory procedures (Archer, 1966; Christal, 1970; Morsh and Archer, 1967) are probably the most developed and rigorous of the various methods for establishing commonalities within limited occupational categories. These procedures are currently being adapted by Borcher and Pratzner for application to civilian jobs.[8]

## Activity Statements Applicable to Jobs in General

The studies described in the remainder of this review have employed activity statements with general applicability.

In discussing the use of activity statements for job analysis purposes, McCormick (1959, 1964) has made the distinction between "job-oriented" work activities and "worker-oriented" variables. By McCormick's definition, a job-oriented activity statement is a description of a job operation in terms of what is accomplished (e.g., "bakes bread"), whereas a worker-oriented activity statement describes the worker's behavior (e.g., "manually pours ingredients into container"). McCormick suggests that worker-oriented activity statements are more suitable for describing a wide variety of jobs, since these descriptors, as opposed to job-oriented statements, are independent of the technological aspects of jobs. Allen (1969) has recently reported evidence supporting a worker- versus job-oriented continuum of verbs, though his findings suggest that this continuum is complex rather than unidimensional.

In a study designed to implement the concept of worker-oriented job activities, Palmer and McCormick (1961) constructed a checklist of 177 items describing various worker-oriented variables. These items were developed under the following categories: (1) Information-Receiving Activities, (2) Mental Activities, (3) Supervisory and Communications

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[8] Ibid.

Activities, (4) Manual Activities, (5) General Bodily Activities, (6) General Work Conditions, and (7) General Job Characteristics. A sample of 250 job descriptions was selected from the files of a large steel producing firm, and these descriptions were rated with the previously described checklist. The data were analyzed in two stages. First, a separate factor analysis was performed on the items within each of the forenamed categories; 14 factors emerged from these analyses. Next, scores on the 14 factors were derived for all jobs in the sample and these scores, along with the scores of 14 checklist items, were intercorrelated. The resulting 28 X 28 correlation matrix was subjected to principal components factor analysis, yielding four factors: (1) General Decision Making and Mental Activity; (2) Sedentary vs. Physical Activity; (3) Communications in Business Management vs. Information in Routine Physical Work; and (4) Knowledge of Tools vs. Mathematics. From these results, the investigators concluded that it was feasible to measure jobs in terms of worker-oriented activity elements and that such elements could be reduced through factor analysis to ". . . a smaller number of relatively independent dimensions."

The conceptual approach taken by Palmer and McCormick was further developed in a subsequent series of studies reported by McCormick and others. The first stage of this research effort (Cunningham and McCormick, 1964a; Gordon and McCormick, 1963; McCormick, Cunningham, and Gordon, 1967) involved the development and analysis of a new job-rating inventory titled the Worker Activity Profile (WAP). Like its predecessor, the WAP contained worker-oriented job variables; but the items in the WAP were developed on the basis of previous research in item construction (Gordon and McCormick, 1962; Peters and McCormick, 1966) and were thus considered to be somewhat more refined than those in the original instrument. Two samples of jobs were drawn for rating purposes: one sample of 400 jobs was based on proportions of jobs in various occupational categories; another sample of 371 jobs was based on the proportions of people in occupational categories. Following ratings of these jobs on the WAP, a series of six factor analyses was carried out separately with each sample of jobs. One analysis included 119 items which had met the criteria for inter-rater reliability and frequency of use. The other analyses were performed separately on the following groups of items: Mediation Activities, Physical Output Activities, Communications Activities, Situational Aspects, and Environmental Aspects. When the factors emerging from these analyses were compared across the two samples of jobs, 22 of the 28 factors from the first sample met the criteria for congruence with factors obtained in the second sample, thus indicating a substantial correspondence between the independently derived factor structures. It was concluded from these results that ". . . there is substantial 'structure' in the domain of human work as one looks at human work in terms of human behaviors and the contextual and environmental attributes of the work situation." (McCormick, Cunningham, and Gordon, 1967, p. 429)

The second stage of research with the Worker Activity Profile involved an exploratory attempt to determine the usefulness of worker-

oriented activity descriptors in estimating the human attribute requirements of jobs (Cunningham and McCormick, 1964b; McCormick, Cunningham, and Thornton, 1967; Thornton and McCormick, 1964). Forty-two human attributes were originally selected for this purpose. Most of these had been previously used by the U. S. Employment Service and fell into the categories of aptitudes, motor abilities, temperaments, interests, and physical capacities. In order to establish a link between the WAP items and the various attributes, the investigators asked a group of graduate students in psychology to rate every item on the extent to which the attribute in question contributed to performance of the defined activity. Weights were then derived for each WAP item on each of the 42 attributes by averaging across raters. These weights made it possible to obtain an attribute-requirement score for a job in two ways: by summing the cross-products between WAP item ratings for the job and item weights on the specified attribute (Cunningham and McCormick, 1964b), or by summing the cross-products between WAP factor scores for the job and attribute-requirement weights for the factors (Thornton and McCormick, 1964). It was thus possible to obtain attribute requirement scores for 401 jobs on each of the 42 human attributes.

In the first analysis of attribute requirement scores, the WAP attribute scores of the 401 jobs were compared with direct trait ratings obtained by the U. S. Employment Service for these same jobs. When Pearsonian product-moment correlations were computed between 37 sets of WAP attribute scores and corresponding USES trait ratings, all but six of these correlations were significant in the expected direction, with the highest agreement occurring among the aptitudes and motor abilities.

The second analysis in this phase of the investigation involved the use of WAP attribute scores in predicting test validities. For this purpose, a sample of 43 Navy jobs was rated with the WAP, and attribute scores for these jobs were derived by the previously described procedure. The attributes selected for this analysis included general intelligence, numerical ability, clerical perception, and mechanical ability. Corresponding to these attributes were validity coefficients obtained for each of the 43 Navy jobs with the following tests: the General Classification Test (an intelligence test), the Arithmetic Test, the Clerical Test, and the Mechanical Test. It was reasoned that if a job received a high score on a given attribute based on its WAP rating, then a test designed to measure that attribute should be a valid predictor of success on the job; conversely, one would not expect the test to be valid for a job receiving a low WAP score on the attribute in question. Based on this rationale, the WAP attribute scores of the 43 jobs were correlated with the validity coefficients obtained for these jobs using tests corresponding to the specified attributes. One or more of these correlations were computed for each of the four previously named attributes, using WAP attribute-requirement estimates based on both item and factor scores. (In the case of the Numerical and Mechanical attributes, correlations were computed with total and subtest scores.) Of the nine correlations computed from attribute scores based on WAP items, six were statistically significant; all of the nine correlations computed from

attribute scores based on WAP factors were significant. The investigators concluded that their results support the feasibility of estimating the human attribute requirements of jobs from ratings on a job-analysis instrument such as the WAP.

Subsequent to the WAP studies, McCormick, Jeanneret, and Mecham (1969a) constructed the Position Analysis Questionnaire (PAQ), a markedly improved job-analysis inventory containing 194 worker-oriented descriptors. (A recent supplement to the PAQ contains 21 additional items, increasing the total to 215 items.) The items in the PAQ were organized into six categories corresponding to the following components in an information-processing (or stimulus-organism-response) paradigm: (1) Information Input, (2) Mental Processes, (3) Work Output, (4) Relationships with Other Workers, (5) Job Context, and (6) Other Job Characteristics. Upon completion of the PAQ, the investigators conducted three studies which paralleled to some extent the previously summarized WAP studies.

In the first PAQ study (Mecham and McCormick, 1969b), psychologists and graduate students in psychology assigned ratings on the "relevance" of 68 human attributes (aptitudes, temperaments, and interests) to each of 178 PAQ items. The average rating of 12-15 judges for a single attribute on a single PAQ item constituted an attribute-requirement estimate for that item; in this way, a profile of 68 attribute-requirement estimates was obtained for each PAQ item. In most cases, the reliabilities of the attribute weights exceeded .80, a level of reliability which justified the subsequent use of the PAQ in the investigation of the aptitude and other attribute requirements of jobs.

The next phase of the PAQ project involved the derivation of basic job dimensions from the PAQ items (Jeanneret and McCormick, 1969). The investigators stated their rationale as follows: "It is hypothesized that there is some underlying 'structure' or order to the domain of human work, and that the variables that characterize this structure can be identified and dealt with in reasonably objective terms [p. 1]." In one part of this study, job analysts within 70 participating organizations rated a total of 536 jobs on the PAQ. The resulting data were then used in a series of seven factor analyses: an overall factor analysis of 150 PAQ items judged suitable for this purpose, and six separate factor analyses of items within the major divisions of the PAQ. Five factors emerged from the overall analysis: (1) Decision/Communication/Social Responsibilities, (2) Skilled Activities, (3) Physical Activities/Related Environmental Conditions, (4) Equipment/Vehicle Operation, and (5) Information Processing Activities. The six component analyses produced 27 interpretable factors. In order to test the stability of their factors, the investigators split their total sample of 536 jobs into two subsamples of 268 jobs each. They then repeated the overall factor analysis of 150 items within both job samples and compared factors across the two analyses using Tucker's (1951) coefficient of congruence. This comparison showed the two sets of factors to be ". . . highly congruent indicating substantial stability in the structure of the overall job dimensions." (p. 90)

A second set of factor analyses employed the previously described attribute-requirement weights of PAQ items as a data base. In these analyses, PAQ items were intercorrelated based upon their attribute-requirement profiles, and the resulting correlation matrices were factor analyzed. Separate factor analyses of items within the six major divisions of the PAQ resulted in a total of 21 factors which, though easier to interpret than the factors based upon job ratings, appeared somewhat similar to these factors. At this point, Jeanneret and McCormick (1969) noted that the relative merit of the two sets of factors (i.e., those based upon job ratings versus those based upon attribute ratings) was ". . . highly dependent upon the particular purpose for which the dimensions might be used, and should be the subject of further empirical investigation." (p. 98)

A final study in the PAQ series was designed to test the use of the PAQ for synthetic-validity purposes; that is, to determine its efficacy in estimating the requirements of jobs for human attributes that are measured by tests (Mecham and McCormick, 1969a). The synthetic-validity approach assumes that if human attribute requirements can be established for a general set of work elements, it should then be possible to determine the attribute requirements of any job, based upon the extent to which the various work elements occur in that job. In the case of the PAQ, the investigators were able to derive an attribute-requirement profile for each PAQ factor, based upon the attribute profiles of the individual elements defining that factor. Consequently, it was possible to obtain attribute estimates for any job that had been analyzed with the PAQ, by summing the cross-products of the factor scores for the job times the respective attribute weights for the factors. Attribute-requirement estimates were thus obtained for 179 positions that had been rated on the PAQ. These positions, in turn, corresponded to 90 jobs for which General Aptitude Test Battery (GATB) data were available (through the U. S. Employment Service) in the form of both mean test scores of incumbents and validity coefficients; these data served as criterion variables for the analyses which are described next. In one set of analyses the attribute-requirement estimates for the aforementioned positions were correlated with the mean GATB scores and the validity coefficients for the jobs to which these positions corresponded. In a second set of analyses, multiple correlations were computed between PAQ factor scores for the positions (as independent variables) and the mean GATB scores and validity coefficients for their corresponding jobs (as dependent variables). The results showed that attribute-requirement estimates correlated ". . . rather substantially with the criterion of mean test scores, but very inconsistently with the criterion of validity coefficients." (p. 11) When PAQ factor scores were used as independent variables, rather substantial multiple correlations were obtained, although as in the case where attribute estimates served as independent variables, mean test scores were consistently more predictable than validity coefficients. Based on these findings, Mecham and McCormick concluded that the ". . . results of the study support quite strongly the basic notion that . . . job attribute requirements can be derived synthetically on the basis of reasonably objective job analysis data,

specifically quantitative data that reflect job characteristics and/or job dimensions of a worker-oriented or behavioral nature." (p. 14)

Following the procedures developed by McCormick, the reviewer and his associates have constructed a 622-item job-rating inventory for the purpose of studying job characteristics and commonalities relevant to occupational education (Cunningham, Tuttle, Floyd, and Bates, 1970, 1971). The work elements (items) in the Occupational Analysis Inventory (hereafter referred to as the OAI) were developed under five major categories corresponding to the following components in a closed-loop information-processing system: Information Received, Mediational (or mental) Activities, Work Behavior (or output), Work Goals (the anticipated outcomes of work), and Work Context (the environment in which work performance occurs). The forenamed categories were further subdivided in accordance with conceptual frameworks adapted from such sources as J. P. Guilford's (1966, 1967, 1971) Structure of Intellect, J. W. Altman's (1966) hardware-to-people continuum of vocational capabilities, E. A. Fleishman's (1964) perceptual-motor factors, the functional occupational classification structure in the Dictionary of Occupational Titles (Fine, 1958, 1968; U. S. Department of Labor, 1965b, 1965c), and various technical manuals. Since it was intended that work dimensions and occupational clusters based on the OAI have curricular implications, the investigators deemed it necessary to include "job-oriented" (or content-loaded) as well as "worker-oriented" (content-free) items in the inventory. The work elements, or items, in the OAI were subjected to several factor analyses based on two sets of data: (1) OAI ratings of 800 occupations; and (2) attribute-requirement profiles of the OAI items (containing 103 human attributes), derived through the previously described procedures of McCormick and his associates (McCormick, Cunningham, and Thornton, 1967; Mecham and McCormick, 1969a, 1969b). Although the factors from both sets of data were meaningful and reasonably stable, the factors derived from the attribute data were more easily interpreted and showed greater stability (based on the coefficient of congruence) than those derived from ratings of occupations (Neeb and Cunningham, 1971; Riccobono and Cunningham, 1971a, 1971b). Subsequent phases of the OAI project will involve clustering occupations on the basis of factor-score profiles, and deriving attribute-requirement estimates for occupations and occupational clusters. The resulting clusters and attribute-requirement estimates will then be validated against the actual test scores of incumbents and trainees in the various occupations. The following tests and numbers of occupations are being used for this purpose: (1) Altman's (1966) general vocational capability tests (40 occupations); (2) the General Aptitude Test Battery (250 occupations); (3) the Ohio Vocational Interest Inventory (40 occupations); and (4) the Minnesota Importance Questionnaire (40 occupations). If the results of the validation analyses are encouraging, a subsequent project will be undertaken to develop and validate a short form of the OAI containing items based on the factors obtained from the original OAI. It is felt that such an instrument might be applied to some of the educational problems discussed earlier in this paper (pp. 9-15).

Another investigation of generally applicable work variables has been reported by Sjogren, Schroeder, and Sahl (1967). Based on a review of the literature in the areas of job analysis, job evaluation, psychomotor behavior, and cognitive behavior, the authors identified five major categories of work activities: physical, discrimination, intellectual, responsibility and decision making, and communication. From these five areas, 42 activity items were defined, and the following named rating scales were developed for use with the items: Variety, Precision, Frequency, Importance, Speed, Strength, and Complexity. For each of the 42 items, positions were rated on from four to seven of the preceding scales, depending upon which scales were appropriate for a specified item. These ratings yielded over 200 scores for each position analyzed. Also included in the instrument were checklist items dealing with work context, clerical activities, physical activities, responsibilities, types of personal contact, and types of supervision given and received. In addition to the foregoing variables, certain scores from the DOT worker trait groups were recorded for each position for inclusion in subsequent analyses. Altogether, 329 scores were obtained for each position analyzed. The positions analyzed in this study fell under 83 occupational titles selected from the agricultural and metal working industries. The data were gathered through interviews with five or six incumbents in each of the 83 occupations. The scores from these interviews were then averaged within occupations, yielding one set of 329 scores for each of the 83 occupational titles.

The first phase of the data analysis in Sjogren et al.'s study consisted of three factor analyses of various activity and trait scores. The finding that factors were generally consistent across the three separate analyses was taken as an indication that ". . . the instrument was measuring behaviors that discriminated among occupations in a meaningful manner." (p. 40) In the second phase of the data analysis, occupations were intercorrelated on the basis of the 329 activity and trait scores, and the following three correlation matrices were factor analyzed: a matrix of intercorrelations among the 47 agricultural occupations, a matrix of the 36 metal working occupations, and a matrix of all 83 occupations. The factors emerging from these analyses were interpreted as clusters of occupations with similar behavioral requirements. Four significant factors resulted from the analysis of all 83 occupations: a general industrial factor, a business factor, a production agriculture factor, and a factor of skilled level occupations. The activity variables characteristic of each occupational factor were determined by comparing the item scores of each occupation in the factor with the average item scores for the entire group of 83 occupations. If a large proportion of occupations in a factor scored high on a particular item in relation to the occupations in general, this variable was identified as a behavioral characteristic of the factor. The results of these analyses showed commonalities among occupations across the two broad occupational categories. It is reported, for example, that ". . . occupations in the agriculture industry and agri-business clusters apparently exhibited more commonality of behavior with industrial or business occupations in metal-working than with production agriculture

occupations." (p. 82) The investigators concluded that ". . . the results of the project did offer some curricular implications . . . [and that the] occupational clusters that were identified were reasonable . . . ." (p. 102)

An interesting conceptual approach to job clustering has been reported by Hamreus and Langevin (1967). These investigators have developed a two-dimensional task classification scheme incorporating the DOT worker function categories (Fine, 1955a, b; Fine and Heinz, 1958) and a hierarchical structure of mental processes (Altman, 1966). The total scheme is represented in a function-by-process grid containing 220 cells. Under this system each basic element, or action, in a job task is assigned to one or more of the grid cells by the following procedure: (1) first, the action is examined to determine its involvement with the categories of people, data, and things; (2) under each of the preceding categories judged to be relevant to the action in question, it is next determined what worker function (or activity) is involved; (3) finally, a judgment is made as to what level of mental process is required to perform the specified function. Through this procedure, every task action is assigned one or more three-element codes, each code representing a cell in the function-by-process matrix.

Hamreus and Langevin applied the foregoing classification system in an exploratory analysis of 18 jobs representing eight occupations which, in turn, fell into three broad categories: mechanical, electrical, and symbolic. The jobs were first analyzed for the purpose of identifying their basic tasks; one or two basic tasks were selected in each job for subsequent analysis. For each of the 27 basic tasks selected, a task description was developed consisting of a list of action statements, which constituted the basic units of analysis. By the previously described classification procedure, every task action under each of 27 basic tasks was assigned to one or more cells in the function-by-process grid. Similarity indices were then computed between all pairs of basic tasks on the basis of commonalities in the classifications of their action statements; a cluster analysis of these indices yielded three clusters containing 3 to 11 basic tasks each. (The similarity index and clustering procedure used in this study were developed by Silverman [1966].) When the basic tasks in these clusters were replaced with the titles of their respective jobs, the three clusters were found to be characterized by (1) drafting jobs, (2) truck repair jobs, and (3) electronics and welding repair jobs. The authors cautioned that though these clusters have "high face validity," it would be unwise to generalize from these results because of the rather limited number of jobs and basic tasks employed in the study. It was further noted, however, that these results do have implications for the development of curricula ". . . having a much broader base than is presently the case." (p. 76)

The last study to be described in this review was reported recently by Bennett (1971), who hypothesized three basic dimensions of work: ". . . activities relating to ideas, to people, and to things." (p. 230) Following McCormick's conception of worker-oriented activities, Bennett compiled a list of 25 worker-oriented verbs of common usage. In addition,

10 task descriptions were prepared that were ". . . broadly representative of the expected factors and almost universally familiar." (p. 230) The 10 task descriptions and 25 verbs were then presented to 36 male college students with instructions to rate (on a four-point scale) each verb in terms of its applicability to each task. Thus, 360 ratings were obtained for each verb: 36 ratings on each of 10 tasks. These data were used to obtain a matrix of correlations among the 25 verbs which, in turn, was subjected to a principal-components factor analysis. The four factors emerging from this analysis were defined as follows: (1) Cognitive, relating to ideas; (2) Social, relating to people; (3) Procedural, emphasizing equipment operation; and (4) Physical, consisting of basic physical activities. The first two factors were interpreted as correspondents to the hypothesized "idea" and "people" dimensions, while the Procedural and Physical factors were identified as constituents of the hypothesized dimension relating to things. Bennett concluded that his results partially confirmed the originally hypothesized dimensions.

The activity statements employed by the studies in this part of the review have the advantage of being applicable to a broad spectrum of jobs or occupations; they are relatively "worker-oriented" in comparison to the "job-oriented" activity statements employed by studies which have focused on restricted categories of jobs. For this reason, such statements should prove useful for broad-scale occupational description and classification. (And, in fact, a set of general "worker functions" was used in the preparation of the Dictionary of Occupational Titles [U. S. Department of Labor, 1965b, c].) On the other hand, since the more general (worker-oriented ) activity statements do not describe jobs with as much specificity as do statements prepared for limited occupational categories, the worker-oriented statements would not alone provide the degree of resolution required in the development of focused, or in-depth, vocational and technical curricula. Worker-oriented statements could be used, however, in establishing reasonably narrow occupational clusters which, in turn, could be subjected to more fine-grained analysis (e.g., in terms of specific task statements) for the development of focused curricula. Worker-oriented statements could also provide necessary information about the basic human requirements of such clusters, as well as a basis for comparison among the clusters. Short of advanced vocational and technical education, the worker-oriented approach might prove useful in such undertakings as: (1) the development of occupational awareness and exploration curricula; (2) the development of curricula designed to teach general vocational capabilities; (3) the development of evaluation procedures and instruments for the forenamed curricula; (4) the development of occupationally-related tests, such as general vocational capability tests, vocational interest inventories, and vocational maturity scales; and (5) the estimation of human attribute requirements of occupations (and occupational clusters) for use in vocational guidance and placement.

Of the several procedures reviewed in this section, McCormick et al.'s Position Analysis Questionnaire (PAQ) has the strongest empirical support. In addition to describing jobs in terms of worker-oriented activity dimensions, the PAQ provides estimates of the attribute

requirements of jobs. Attribute-requirement estimation (or synthetic validity) was, in fact, probably the primary purpose for which the PAQ was developed. The Occupation Analysis Inventory (OAI), developed by the reviewer and his associates, represents an attempt to extend McCormick's procedures to problems in occupational education, particularly curriculum development. Consequently, the OAI contains approximately three times as many items as the PAQ, and a number of these items tend to be somewhat job- or content-oriented in comparison to McCormick's items. Even though the OAI does describe jobs at a more specific level than the other procedures reviewed in this section, it is doubtful whether this instrument alone could provide the degree of resolution necessary for the development of focused vocational and technical curricula. Both the OAI and the PAQ might, however, prove useful in dealing with other educational problems, such as those listed in the preceding paragraph. An effort is currently under way to obtain some evidence for the validity of the OAI.

The procedures developed by Sjogren et al. (1967) and Hamreus and Langevin (1967) employed activity variables that are more general than those in either the PAQ or the OAI. Since the item categories in Sjogren et al.'s instrument are based on factors derived in various studies of jobs and human abilities, the total set of items has some empirical basis and should be reasonably comprehensive. The activities in Hamreus and Langevin's scheme are the components in four a priori hierarchical structures. Nevertheless, three of these structures, the DOT worker function hierarchies, find some empirical support in the results recently reported by Bennett (1971). Furthermore, the DOT worker functions, though rather coarse-grained, do seem to cover the entire scope of work activities. Both of the forenamed procedures have the advantage of being shorter than either the PAQ or the OAI--especially the OAI, which contains a rather unwieldy set of 622 items. On the other hand, no direct efforts have thus far been made to validate either Sjogren et al 's or Hamreus and Langevin's procedures, and neither of these two procedures provides estimates of the attribute requirements of jobs.

## DISCUSSION

The introduction to this paper specified four main objectives, three of which (the reviewer hopes) have now been accomplished. The field of ergometrics has been defined, several of its potential applications have been identified, and an attempt has been made to present a reasonably comprehensive survey of the published research in this field, with studies classified under four categories of job descriptors. This section of the paper will summarize the potential uses and limitations of the four kinds of descriptors and then proceed to the final objective, a discussion of some conceptual approaches which might be used in conjunction with ergometric procedures.

Attribute-requirement estimates obtained through direct ratings of jobs on human attributes can be useful for such purposes as guidance, selection, and placement--if the ratings are reliable and valid. However, the task of directly estimating the attribute requirements of jobs would seem to be a rather demanding one, since descriptions of human attributes are rather abstract in comparison to activity descriptions. There is, nevertheless, some evidence for the validity of such ratings (Trattner, Fine, and Kubis, 1955; Primoff, 1959). An alternative approach to estimating the attribute requirements of jobs involves obtaining attribute weights for a set of basic work-activity statements which, in turn, are used in rating jobs. This method, termed "synthetic validity," also has some empirical support (McCormick, Cunningham, and Thornton, 1967; Mecham and McCormick, 1969a). In addition, the synthetic validity method has two advantages over the direct-rating approach: (1) activity statements are more concrete and therefore presumably more ratable than attribute statements; and (2) this method provides job descriptions in terms of work activities, as well as attribute requirements. If, on the other hand, the sole purpose of an analysis is to determine the attribute requirements of a job, the direct-rating method is considerably less time-consuming than the synthetic-validity procedure. Although the comparative validity of the two approaches has not been investigated, McCormick, Cunningham, and Thornton (1967) found substantial correlations between attribute-requirement estimates obtained by these two procedures. The reviewer and his associates are currently gathering data which will allow a limited comparison of the two methods against the criteria of average test scores and validity coefficients in a sample of approximately 80 occupations.

Knowledge and skill statements, though usually more concrete than attribute definitions, do nevertheless require some inference concerning the internal state of the job incumbent. For this reason, such statements are subject to the same criticism that has been directed against implicit (versus behavioral) statements of instructional objectives (cf, DeCecco, 1968; Mager, 1962). Although ratings of jobs in terms of knowledge and skill requirements can provide information applicable to curriculum development, the following alternative would seem more desirable: If the investigator finds knowledges and skills to be useful

constructs, he could generate a set of activity or task statements for each of a number of defined knowledges and skills, and then analyze jobs on the basis of these activity statements. This approach would probably produce both a more ratable job-analysis inventory and more interpretable results than could be obtained through the use of knowledge and skill statements. The investigator could, moreover, convert activity ratings of jobs into knowledge- and skill-requirement estimates, if he wished to compare jobs on that basis. Such a procedure was used in the previously described study by Thorndike et al. (1957) to obtain attribute-requirement estimates for jobs.

Task statements that are prepared for restricted categories of jobs are applicable in the development of specific, or focused, vocational and technical curricula. In addition, such statements might prove useful in curriculum evaluation and the development of specific trade tests. Because of their restricted scope, however, specific task statements are not very useful for comparisons across wide ranges of jobs. For broad-range job description and classification (i.e., the comparison and grouping of a variety of jobs), it is necessary to apply more general (or worker-oriented) activity statements, such as those contained in McCormick et al.'s Position Analysis Questionnaire or the Occupation Analysis Inventory developed by the reviewer and his associates. As suggested earlier, an inventory composed of worker-oriented activity statements might be used to form occupationsl clusters and to describe these clusters in terms of general work-dimension and attribute-requirement profiles; the resulting clusters could then be subjected to more fine-grained analyses through procedures such as those developed by the Air Force (Christal, 1970; Morsh, 1964, 1969) and those currently under development at the Center for Vocational and Technical Education (1970a, b, c, d).[9] Worker-oriented statements might also find application in such undertakings as: the development of occupational awareness and exploration curricula, and curricula directed toward general vocational capabilities; the development of curriculum evaluation procedures; the development of occupationally related tests, such as general vocational capability tests, vocational interest inventories, and vocational maturity scales; and the estimation of the human attribute requirements of occupations and occupational clusters, for use in vocational guidance and placement.

With the exception of Ghiselli's (1966) research, the studies described in this review had at least one aspect in common: tasks, positions, jobs, or occupations were rated on various characteristics, and these ratings were used as data in subsequent analyses. Other types of procedures have, of course, been used in the study of work-related phenomena. Ghiselli, for example, compared and grouped occupations on the basis of test validity data; alternatively, occupations could have been grouped on the basis of average test profiles of incumbents.

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[9] Ibid.

Guilford (1967, 1971), Fleishman (1964, 1967,a), and other ability theorists have grouped tasks (tests) in terms of the response consistencies of subjects performing the tasks (i.e., correlations among test scores). Once task factors, or dimensions, have been established (based on task intercorrelations), tasks representing these factors (i.e., reference tests) can be used in the subsequent analysis of other tasks (Fleishman, 1967b). In a study conducted by Altman and his associates (1966), test items were developed from a broad range of occupational task descriptions, and subjects' responses to these items were used in defining a continuum of vocational capabilities. Altman's procedure of deriving test items through job analysis might be used, in conjunction with the factor-analytic approaches of Guilford and Fleishman, to define and measure various work-related attributes in the cognitive, psychomotor, and affective domains.

Another interesting line of research, initiated at the University of Minnesota, employs an associative-response technique developed by verbal-learning psychologists (Deese, 1962, 1965; Garskof and Houston, 1963; Johnson, 1965, 1967). Under this procedure, lists of job-related technical terms are used to elicit verbal associative responses from job incumbents. The resulting response distributions serve as a basis for interrelating the various terms and extracting (through factor analysis) basic conceptual dimensions within occupations (Moss et al., 1970; Pratzner, 1969; Pucel, 1966; Smith, 1968). Since the verbal association procedure is very time-consuming, it is probably best suited for intensive analyses within occupations or narrow ranges of occupations. It might be used, for example, in defining conceptual structures of occupations that have first been analyzed (and perhaps grouped) by the task-inventory procedure. Moreover, the associative-response approach could conceivably be used in comparing occupations within restricted categories.

Much of the research on job commonalities has lacked adequate conceptualization. Although part of this problem can be attributed to the investigators' failure to use available conceptual tools, the major difficulty has probably been the scarcity of appropriate concepts. Within recent years, however, a number of conceptual schemes have emerged which should lend themselves to ergometric research. Among these is the conception of man as an information-processing system, as an entity which transforms information inputs into prescribed outputs. Indeed, several investigators have recognized the potential utility of an information-processing approach to task and job analysis (Gagné, 1962b; McCormick, Jeanneret, and Mecham, 1969a; Miller, 1962; Stolurow, 1964a, 1964b). At least two ability theorists have also adopted the information-processing paradigm: Guilford's (1966, 1967) Structure of Intellect treats man as an information processor, and Fleishman (1967a, 1969) has defined "abilities" as ". . . capacities for processing different kinds of information." (1969, p. 350) Since Guilford's Structure of Intellect is essentially a classificatory framework for basic cognitive tasks (the classes of tasks being embodied in various ability tests), this model should prove useful in the analysis and classification of cognitive tasks in jobs. Analogously, Fleishman's perceptual-motor factors, though not

based on an explicit conceptual model, might find application in the analysis of the psychomotor aspects of jobs. Several investigators have, in fact, applied the contributions of Guilford and Fleishman to the problem of work analysis. Thus, Mecham and McCormick (1969a, b) and Theologus and Fleishman (1969) have developed procedures for estimating requirements of jobs and tasks on various ability factors, most of which were identified by Guilford and Fleishman. In addition, Cunningham and his associates (1970) have incorporated certain aspects of Guilford's model and some of Fleishman's factors into the structure of the Occupation Analysis Inventory, and Gilpatrick (1970) has reported a procedure for rating tasks on 41 "general intellectual skills" derived from Guilford's model.

Another concept that might find use in ergometric research and development is Gagné's (1962a, 1968, 1970) idea of vertical transfer, involving capability hierarchies which progress from basic, general task capabilities to increasingly complex and specific task capabilities. Under this scheme, a capability at a given level in a hierarchy depends upon the previous acquisition of a set of more general prerequisite capabilities--i.e., a capability at a given level of complexity is acquired through the successive acquisition and transfer of less complex capabilities. Since a capability is manifested in task performance, a capability hierarchy would be operationally defined in terms of classes of tasks and standards for task performance, such that for a given class of tasks, a set of more basic antecedent classes of tasks could be identified. For example, the capability to solve linear algebraic equations requires a number of subordinate task capabilities, including: addition, subtraction, and multiplication of numbers in sequence; division of parenthetical terms; combining fractions with like denominators; simplifying fractional expressions; simplifying equations by adding and subtracting arithmetic numbers to both sides; etc. (Gagné and Paradise, 1961).

Under the conception of vertical transfer, the capacities measured by standardized aptitude tests might be considered as very general and basic task capabilities which have been overlearned to the point of relative stability (Ferguson, 1954, 1956) and which are transferable to a wide variety of more specific and complex capabilities (Fleishman, 1967b). Proceeding further, it might be reasonable to think of specific job proficiencies as the products of a developmental process progressing in a sequence of stages such as the following: (1) aptitudes and basic educational skills; (2) general vocational capabilities; (3) focused, or in-depth, vocational and technical capabilities; (4) proficiencies at tasks in a specific work position, some of which are, in turn, transferable to subsequent positions in the individual's career (Cunningham, 1969). (Presumably, the individual's learning experiences could be arranged throughout his lifetime in such a way as to optimize his career development.) If this conception is viable, it should be possible to identify the antecedent, or subordinate, capabilities for a specified class of tasks at any stage in a developmental progression--

e.g., the minimum aptitude requirements for a general vocational capability, the general vocational capability requirements for a more focused work capability, or the prerequisite work experience for advancement to a particular job. The vertical-transfer assumption seems implicit in the work on synthetic validity: under the synthetic validity approach, estimates are obtained of the extent to which each of a set of job elements (usually classes of work activities or tasks) requires a number of specified aptitudes (capabilities to perform classes of basic cognitive and perceptual-motor tasks).

A multi-level task taxonomy with vertical linkages such as those just suggested might be applied in the development of sequential educational programs, beginning with basic educational skills and progressing through specific occupational preparation; a vertical taxonomic scheme should also have implications for career progression beyond formal education. As mentioned earlier, the development of a comprehensive and cohesive taxonomy of work will require considerable time and effort on the part of many future investigators. But in the interim, it might be possible to establish crude linkages between existing classification schemes which have dealt with work at different levels of specificity and complexity, even though these schemes are based on different conceptual approaches. Such linkages between different levels of classification might, in turn, provide a basis for tracing (albeit somewhat imprecisely) developmental progressions for various work capabilities. Some examples of potentially useful classification efforts, in increasing order of their specificity of application, include: (1) the task description and classification schemes of Stolurow (1964a, 1964b, 1966) and Farina and Wheaton (1969); (2) the factor-analytic work of Guilford (1967, 1971) and Fleishman (1964, 1967a) in the cognitive and psychomotor domains, respectively, and the task-rating procedure reported by Theologus and Fleishman (1969); (3) McCormick et al.'s application of the concept of worker-oriented job elements, as embodied in the Position Analysis Questionnaire (McCormick, Jeanneret, and Mecham, 1969a); (4) the Occupation Analysis Inventory developed by Cunningham and his associates (Cunningham, Tuttle, Floyd, and Bates, 1970, 1971); and (5) various inventories developed for restricted ranges of jobs (e.g., Morsh, 1965; Hemphill, 1959; Rahmlow, Johnson, and Cavanagh, 1966; the Center for Vocational and Technical Education, 1970a, b, c, d).

In addition to the concept of capability (or learning) hierarchies, Gagné (1970a, 1971a, 1971b) has proposed that capabilities can be classified into four domains that are distinguishable in terms of learning process. These four domains include: motor skills, verbal information (knowledge), intellectual skills (discriminations, rules, and concepts), and cognitive strategies for problem solving (especially creative problem solving). Gagné also proposes a fifth domain, attitudes, which involves still another learning process. According to Gagné, the five domains are "orthogonal to 'content'" and must be treated differently in a educational setting. Thus, within a selected subject area, learning situations should be designed for each of the separate domains in order to achieve a desirable balance of capabilities and attitudes.

Furthermore, tests designed to measure educational outcomes should deal separately with each of the five domains. The relevance of Gagné's domains would seem to warrant consideration in the field of ergometrics. The most obvious implication is that tasks should be described and classified not only by content but also by learning process. For a given task or class of tasks, the prerequisite capability requirements in each of the domains should also be considered, as well as the selected learner's state of development in each domain.

Also relevant to ergometrics are various theories and constructs pertaining to work motivation. Prominent among these are: Herzberg's two-factor theory (Herzberg, 1966; Herzbert et al., 1959); the expectancy theories of Vroom (1964) and Porter and Lawler (1968); Alderfer's (1969) E.R.G. (existence, relatedness, and growth) theory; and Dawis et al.'s (1964, 1968) theory of work adjustment. Just as capabilities can be defined in terms of how well one can perform specified classes of tasks, motives can be defined in terms of one's preferences for (i.e., tendencies to approach or avoid) specified classes of tasks, outcomes, and conditions; and, conversely, these classes of work characteristics can be considered to possess varying degrees of reinforcement value (positive or negative), depending upon the motivational state of the individual in question (Lofquist and Dawis, 1969).

Since the reinforcement values for various classes of work characteristics vary among individuals, motivation often moderates the relationship between capability and performance--i.e., performance is a function of the interaction between motivation and capability. When capability is held constant above a minimum required level, motivation should determine the nature and extent of an individual's participation in a work situation. Thus, given the minimum capability to perform a task or job, the individual may, depending upon his motivational state, adopt one of three general response modes: he may (1) perform the task or job according to the prescribed rules, (2) participate in the work situation under his own rules (i.e., deviate from the prescribed procedures and outputs), or (3) refuse to participate in the work situation (e.g., quit his job).

Presumably, an individual's mode of response in a particular work situation could be predicted by comparing appropriate measures of his chronic motivational condition (e.g., interest and need profiles) with measures of the corresponding reinforcement properties of the job in question. Much of the previous research on motivation and work has dealt with relationships between affective (motivational) measures and the criterion of job satisfaction, a variable which in turn has been found to be rather consistently related to response mode 3 (i.e., tenure and absenteeism) but only tenuously related to response modes 1 and 2 (i.e., performance) (Brayfield and Crockett, 1955; Kahn, 1960; Vroom, 1964). Recent attempts have been made, however, to establish a direct relationship between degree of motivation-reinforcement match and work behavior (Cleff and Hecht, 1971; Hackman and Lawler, 1971); and this research trend should become increasingly feasible with further

refinement in measures of work motivation and the corresponding reinforcement characteristics of jobs. The instruments developed on the Work Adjustment Project at the University of Minnesota (Lofquist and Dawis, 1969; Weiss et al., 1966) and by Hackman and Lawler (1971) at Yale represent notable efforts in this direction.

In addition to new conceptual apparatus and work-analysis techniques, improved data-analysis and processing tools are now at the researcher's disposal. Factor-analytic procedures, which have been used for a number of years in the study of work dimensions, have been improved and, in combination with increased computer capabilities, permit analyses involving large numbers of variables and observations. Recently developed cluster-analysis procedures are proving valuable in task and job classification (Christal, 1970; Morsh, 1965, 1969; Silverman, 1966, 1970; Ward, 1961; Ward and Hook, 1963). Among other procedures which could prove useful are discriminate analysis and multivariate analysis of variance, which might, for example, be used to investigate differences among occupations and occupational clusters in terms of various dependent-variable measures, such as test scores of job incumbents (cf, Prediger, 1971b; Pucel et al., 1970, 1971; Schoenfeldt, 1970).

In summary, it would seem that sufficient conceptual, measurement, and mathematico-statistical tools are currently available to support a systematic and comprehensive approach to the study of work which might be called "ergometrics." This field of investigation has potential application to a number of problems in occupationally related, or career, education.

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